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Estimating the Burden of Disease Associated with Outbreaks Reported to the U.S. Waterborne Disease Outbreak Surveillance System: Identifying Limitations and Improvements

National Center for Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH

NOTICE

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LIST OF ABBREVIATIONS

AGI	Acute gastroenteritis illness of unknown etiology
AIDS	Acquired Immunodeficiency Syndrome
CAST	Council for Agricultural Science and Technology
CDC	Centers for Disease Control and Prevention
COI	Cost-of-illness
CPI	Consumer Price Index
DALY	Disability Adjusted Life Year
ER	Emergency room
HCUP	Health Care Utilization Project
PCG	Productivity losses of caregiver
PI	Productivity losses of ill person
PV	Physician visit
SDWA	Safe Drinking Water Act
SM	Self-medication
SRSV	Small round structured virus
U.S. EPA	U.S. Environmental Protection Agency
VSL	Value of statistical life
WBDO	Waterborne disease outbreak
WBDOSS	Waterborne Disease Outbreak Surveillance System
WTP	Willingness to pay

GLOSSARY

Benefit-cost analysis (BCA) — A type of economic analysis in which all costs and benefits are valued in monetary terms and results are expressed as either the net social benefit or the ratio of benefits to cost.

Conventional economic theory — The collection of premises that attempt to describe the allocation of resources among consumptive uses, given consumer preferences, societal restrictions or regulations, and environmental constraints. This theory focuses on the maximization of utility or satisfaction level.

Cost-effectiveness analysis (CEA) — A type of economic analysis in which costs are valued in monetary terms and health benefits are valued in epidemiologic units. These analyses compare alternative medical treatments or public health strategies.

- *Cost-utility analysis* (CUA)*:* a subset of cost-effectiveness analysis in which costs are valued in monetary terms and health benefits are expressed as summary population health measures (e.g., DALYs and QALYs). Medical decision-makers rely on cost-utility analyses to compare alternative medical treatments.

Cost-of-illness (COI) method — An approach to estimate the impacts of a disease by examining two types of costs incurred by an ill person: the direct medical and nonmedical costs associated with the illness and the indirect costs associated with lost productivity due to morbidity or premature mortality.[1]

- Direct costs — The measure of the resources expended for prevention activities or health care (compare with indirect cost).
    - Direct medical costs — The measure of the resources for medical treatment (e.g., the cost of a physician visit).
    - Direct non-medical costs — Those costs incurred in connection with a health intervention or illness, but which are not expended for medical care itself (e.g., the transportation costs associated with a physician visit).
- Indirect costs — The resources forgone either to participate in an intervention, as the result of an injury or illness (e.g., earnings forgone because of loss of time from work, earnings forgone because of reduced productivity at work), or to provide care to an ill individual.

Disability adjusted life years (DALYs) — A summary public health measure that was developed for the Global Burden of Disease Study. For an illness, a DALY is measured by summing the quantity of life lost due to premature death and the quantity of time lived with a disability due to a disease. The quantity of life lost due to the illness can be calculated by subtracting the age at which a death occurs from the standard life expectancy for the population. The quantity of time lived with a disability is computed as the product of the utility weight (defined below) for the health condition (for DALYs this is normally referred to as a disability weight) and the length of time lived with the

[1] The costs associated with premature mortality are not examined in this report. Some costs associated with morbidities are also not addressed (e.g., transportation costs and presenteeism).

disability. Some applications of DALYs employ an age weighting factor. DALYs are frequently used in cost-utility analyses (defined above).

Outbreak — Two or more cases of illness that occur following a common exposure.

Person-days ill — A quantity describing the length of time individuals in an epidemiologic study are ill with the disease of interest. For example, a person that is sick for one day would contribute one person-day ill towards the epidemiologic measure.

Quality adjusted life years (QALYs) — A summary public health measure that incorporates the quality or desirability of a health state with the duration of survival. For each health state that an individual experiences, a utility weight (defined below) is assigned. The length of time lived with a specific condition and the utility weight are multiplied. For each condition experienced during a lifetime, these products are summed to estimate the quality adjusted life years an individual experiences. QALYs are frequently used in cost-utility analyses.

Utility — An economic concept that describes an individual's perception of satisfaction for one outcome over another.

Utility weight — The numeric value assigned to an impact (value of a health state). This is a quantitative measure that indicates the relative strength of an individual's preference for one outcome over another. In public health, utility suggests the relative desirability of a particular health outcome or health state. These preferences are based on elicited values of a rater (typically a patient or a member of the general public) for that outcome relative to some defined health alternatives.

Willingness to pay (WTP) — In the context of this document, it is a measure of the value an individual places on reducing the risk of some event (e.g., death or illness). It is estimated as the maximum dollar amount an individual would pay preceding a given risk-reducing situation.

PREFACE

This report was developed by the U.S. Environmental Protection Agency's (U.S. EPA) Office of Research and Development (ORD), National Center for Environmental Assessment in collaboration with researchers from Craun and Associates, Inc. It contains information concerning a waterborne disease outbreak database that has been jointly maintained by the Centers for Disease Control and Prevention (CDC) and the U.S. EPA since 1971. The document examines waterborne outbreaks from the perspective of disease burden. The term *disease burden* is a general expression that is used to capture the magnitude of the health impacts that occur; it generally refers to decrements in a population's health, but can include the associated economic burden. This effort supports research mandated by the Safe Drinking Water Act (SDWA) Amendments of 1996. Specifically, section 1458(d) requires the U.S. EPA and CDC to develop a national estimate of waterborne disease occurrence ("the national estimate"); specifically, it identifies research needed to improve estimates of the outbreak component of waterborne disease occurrence. This research also addresses the need for improved understanding of the impact of waterborne microbial risks in the U.S.

AUTHORS, CONTRIBUTORS AND REVIEWERS

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On October 26-27, 2006, the external review draft version of this report titled "Approaches to Estimating the Waterborne Disease Outbreak Burden in the United States: Uses and Limitations of the Waterborne Disease Outbreak Surveillance System" (EPA/600/R-06/069) was independently externally peer-reviewed by Versar, Inc. under EPA contract number. 68-C-02-061, Task Order No. 78. EPA released this draft document solely for the purpose of pre-dissemination peer review under applicable information quality guidelines. This document was not formally disseminated by EPA. On September 15, 2006 (71 FR 54481), EPA announced a 30-day public comment period for the draft document. The public comment period ended October 16, 2006. In their deliberations, the peer-review panel considered all comments submitted to the docket and oral comments provided during the peer-review meeting by a registered observer, Ms. Ann Seeley from the New York City Department of Environmental Protection, representing AWWA. The peer-review panel included the following individuals:

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EXECUTIVE SUMMARY

INTRODUCTION

The dramatic reduction in the incidence of waterborne infectious diseases due to filtration and chlorination of public drinking water supplies and effective sewage treatment is one of the great public health achievements of the 20th Century. Although water treatment technologies and protection of water sources are mandated along with other practices in order to reduce the risk of waterborne disease in the U.S., outbreaks still occur.

Information about U.S. waterborne disease outbreaks is voluntarily reported to the Waterborne Disease Outbreak Surveillance System (WBDOSS), which is maintained by the Centers for Disease Control and Prevention (CDC), the U.S. Environmental Protection Agency (U.S. EPA), and the Council of State and Territorial Epidemiologists. State, territorial and local public health agencies are responsible for detecting and investigating waterborne outbreaks and reporting them to this passive surveillance system. The CDC and U.S. EPA evaluate the outbreak reports to assess the strength of the epidemiologic evidence implicating water and the available information about water quality, sources of contamination and system deficiencies. Information about the occurrence of outbreaks and their causes is published biennially in the *Morbidity and Mortality Weekly Report*. The illnesses that occur during these waterborne outbreaks can range from mild episodes of gastroenteritis to severe outcomes that can result in dehydrating diarrhea, serious sequela such as hemolytic uremic syndrome (HUS), hospitalization or death.

The purpose of the analyses presented in this document is to investigate the utility of archived waterborne outbreak reports as a surveillance-based approach to estimate a portion of the waterborne disease burden. We apply the burden estimation methods described herein to non-recreational waterborne outbreaks that occurred in the U.S. between 1971-2000 and were reported to the WBDOSS.

It is important to note that limitations inherent in the outbreak reporting system preclude estimation of the actual incidence and aggregate burden of outbreak-related waterborne illnesses on a national scale. This analysis of outbreak reports does not attempt to provide an estimate of the actual incidence and burden of outbreak-related waterborne illnesses in the U.S. because such an estimate would require additional data and procedures to estimate unreported outbreaks and unrecognized cases. Unreported outbreaks and cases are not considered in this report. Rather, the purpose here is to explore the potential to develop outbreak disease burden measures from available

outbreak surveillance data, examine the impact of missing information on the resultant burden estimates, and highlight aspects of outbreak reporting that, if improved or added to the current system, would enhance the potential to develop outbreak burden estimates in the future. The methods developed here may provide valuable tools for future U.S. EPA waterborne disease outbreak burden analyses. Similar to the biennial surveillance summaries of waterborne-disease outbreaks published in CDC's Morbidity and Mortality Weekly Report, we compared the burden estimates across reported outbreak characteristics including the etiologic agent, type of source water, water treatment system, and attributed deficiency.

LIMITATIONS OF THE WBDOSS FOR ASSESSING DISEASE BURDEN

Table ES-1 lists important limitations of the waterborne disease outbreak surveillance system and the consequences of the limitations for this analysis. An important limitation of the WBDOSS data set is that not all waterborne outbreaks and associated cases of illness are recognized or reported. The reported outbreak events and characteristics do not reflect the true number of outbreaks or incidence of disease, and the extent to which outbreaks are not recognized, not investigated or not reported is unknown. Whether an outbreak is reported depends on many factors including: (a) public awareness, (b) the likelihood that persons who are ill will seek treatment and consult the same health-care providers, (c) availability and extent of laboratory testing, (d) local requirements for reporting cases of particular diseases and (e) the surveillance and investigative activities of state and local public health and environmental agencies.

In addition, not all outbreaks are rigorously investigated and outbreak information may be incomplete. Often the primary intent of an outbreak investigation is to determine the cause and to prevent additional illness; such investigations may not focus on identifying epidemiologic information or water quality data that are important in estimating the disease burden. Thus, our analyses cannot provide a burden estimate of the true incidence of waterborne outbreak illnesses in the U.S. population. Furthermore, the WBDOSS does not include sporadic or endemic cases of waterborne illness. The reader should be mindful of these limitations when comparisons are made between outbreaks that have occurred in different types of source waters, using different types of treatments attributed to different etiologic agents and as a consequence of various treatment deficiencies. Despite these limitations, the WBDOSS database does constitute the most comprehensive source of information on waterborne outbreaks in the U.S. and is useful for demonstrating our surveillance-

TABLE ES-1

Important Limitations of the 1971-2000 Waterborne Disease Outbreak Surveillance System (WBDOSS)

Limitation	Consequence
Limitations Affecting the Reporting of Outbreaks	
• Outbreak reporting to the Federal government was voluntary and there were no nationally consistent reporting 'standards' during the 30-year study period	• WBDOSS study data represent only a portion of the outbreaks that occurred in the U.S. during the 30-year study period
• Surveillance was passive and recognition and investigation of outbreaks dependent upon: o public awareness of the outbreak o availability of laboratory testing o local requirements for reporting diseases o resources available to the local health departments o capacities of local public health agencies and laboratories	• Not all outbreaks are detected, especially those that resulted in less serious illness or etiologies that require extensive laboratory testing and have lengthy incubation period • Changes in the number of outbreaks reported could either reflect an actual change in occurrence or change in surveillance sensitivity • Analyses will not include contributions of unrecognized outbreaks to overall burden
Limitations Affecting the Number of Cases and Severity of Illness	
• Case definitions may vary across outbreaks depending upon the signs and symptoms considered important by each investigator	• Number of cases and their severity may not be comparable across outbreaks
• The thoroughness of investigation varies	• Epidemiologic information (e.g., reported or estimated case numbers) may be inconsistent across different outbreaks
• Reporting error, recall bias or other potential epidemiologic biases	• Number of cases may be over- or under-estimated
• Investigators may not provide all of the information requested on CDC 52.12 • Some important severity characteristics (e.g., physician visits, emergency room visits) are not requested on CDC 52.12	• Burden may be underestimated
Limitations Affecting Identification of Etiologic Agent	
• The identification of the etiologic agent depends on: o the capability of the laboratory to test for a particular pathogen o the timely recognition of the outbreak so that appropriate samples can be collected	• Lack of appropriate sampling and analysis relegates classification to "acute gastrointestinal illness of unknown etiology" (AGI) and limits information regarding impact of various etiologic agents
• Outbreaks may be retrospectively investigated to identify the etiologic agent and water system deficiencies	• Evidence of contamination may be transitory and no longer available

based approach for analyzing the reported outbreak component of the infectious disease burden posed by contaminated drinking waters.

MEASURES OF THE BURDEN OF DISEASE

The approach used in this report to determine the burden of waterborne infectious disease outbreaks due to drinking water is illustrated in Figure ES-1. While a variety of measures, such as Disability Adjusted Life Years (DALYs), have been employed to estimate disease burden, we limit this analysis to the benefits assessment measures (i.e., epidemiologic measures and monetary measures) currently employed in U.S. EPA rulemaking procedures. The epidemiologic measures must be obtained or estimated to quantify the monetary measures; uncertainties in the epidemiologic measures will be propagated through the estimates of monetary measures. It is important to note that the quantified epidemiologic burden describes only a subset of the total epidemiologic burden associated with waterborne outbreaks. The monetary burden (expressed in year 2000 U.S. dollars) presented here is consistent with current U.S. EPA economic practices. To estimate the monetary burden associated with the morbidity from waterborne illnesses, U.S. EPA uses cost-of-illness (COI) estimates. For the outbreak analysis, we employed COI data derived from several peer-reviewed sources that provide estimates specifically for waterborne outbreaks; however, the analysis is limited due to a lack of economic studies that could be utilized. It is important to note that the monetary burden quantified in this report also describes only a subset of the total monetary burden associated with waterborne outbreaks.

METHODS USED TO ESTIMATE THE EPIDEMIOLOGIC BURDEN

Table ES-2 summarizes the information available for the 665 infectious waterborne outbreaks reported during 1971-2000. When essential information about illness severity characteristics was inadequately reported for disease burden estimation purposes—either because the information was not requested on CDC 52.12 (i.e., the form investigators use to report outbreaks to the WBDOSS) or the form was incompletely filled out, we estimated values necessary for our analyses. If these data were available, we used information from other outbreaks in the database that were attributed to the same or a similar etiologic agent. If sufficient information was not available from other outbreaks, information was obtained from the scientific and medical peer-reviewed literature. Some 45% of the epidemiologic measures and monetary measures (n=300) were attributed to specific waterborne pathogens that were identified in clinical specimens obtained from the case patients. The other 365

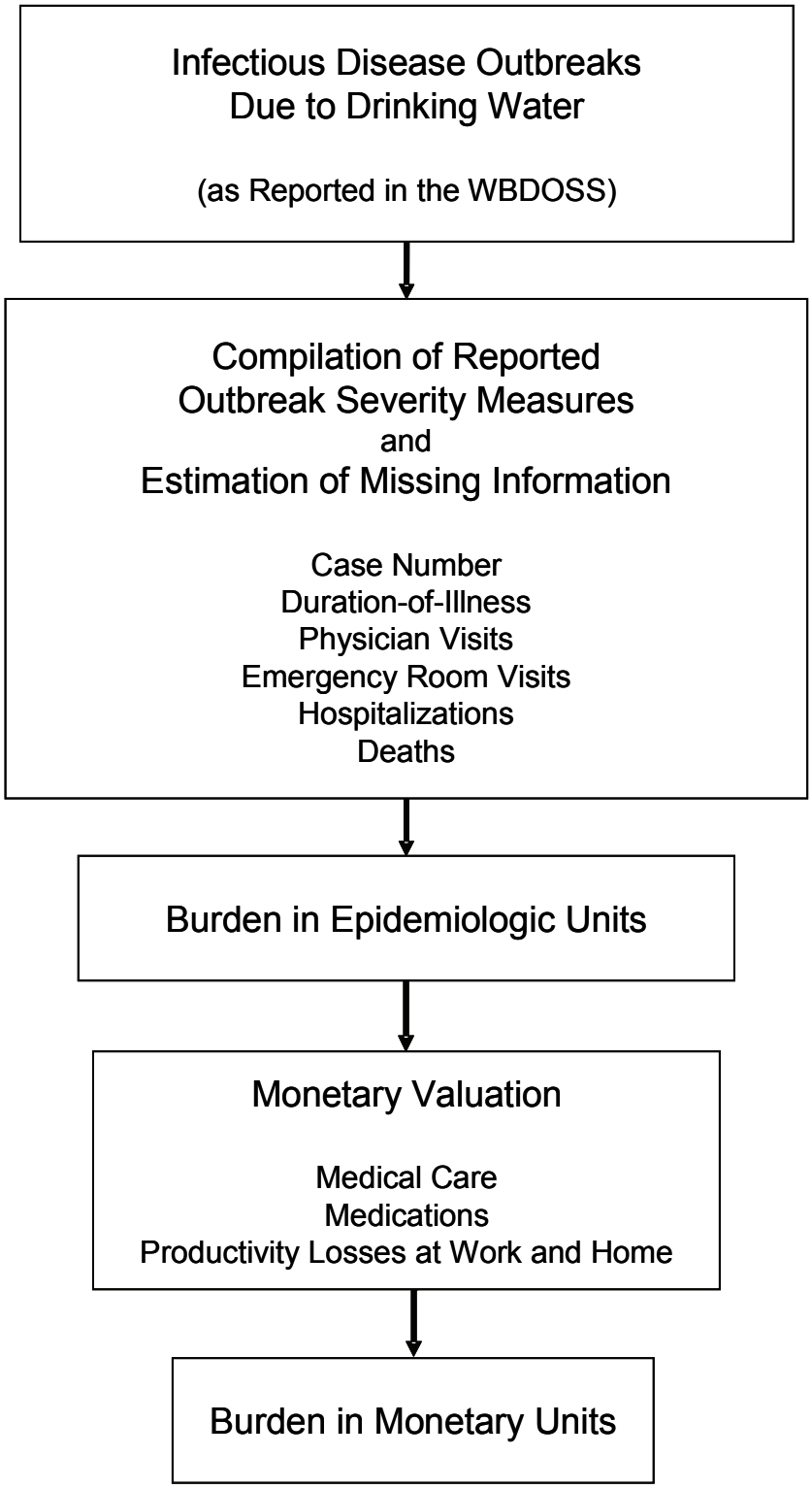


FIGURE ES-1
Methodology to Determine the Disease Burden of Waterborne Disease Outbreaks

TABLE ES-2

Availability of Severity Measures in the WBDOSS (Number of Infectious or Suspected Infectious Drinking Water Outbreaks = 665)

Severity Measure	Outbreaks for Which Severity Measure was Reported		Does CDC 52.12 Request this Measure?
	Number	Percent	
Cases of Illness	665	100	Yes
Duration of Illness	282	42	Yes
Hospital Admissions	659	99	Yes
Physician Visits	29	4	No
Emergency Room Visits	15	2	No
Deaths	665	100	Yes

outbreaks were identified as “acute gastrointestinal illness of unknown etiology” (AGI) either because laboratory results were not reported or an etiologic agent could not be identified by the tests performed.

EPIDEMIOLOGIC BURDEN MEASURES

The summary epidemiologic severity measures used for the epidemiologic burden analysis are presented in Table ES-3.

TABLE ES-3

Epidemiologic Burden Measures Associated with Reported U.S. Waterborne Outbreaks Between 1971-2000

Burden Measure	Value Used	Reported or Estimated
Cases	569,962	Reported
Person-Days Ill	4,504,933	Calculated from reported case numbers and reported or estimated durations of illness
Physician Visits	41,985	Estimated
Emergency Room Visits	23,575	Estimated
Hospitalizations	5,915	Reported
Deaths	66	Reported

Duration of Illness

By multiplying the average duration of illness and the number of cases, we estimated person-days ill associated with each outbreak. This measure provides a succinct way to compare the population-level health impact of different diseases.

Physician and Emergency Room Visits

Form CDC 52.12 does not request information about the number of physician and emergency room visits. When available, we used the physician-visit rate reported in the WBDOSS for the same etiologic agent to estimate unreported rates. For

emergency room visits, most estimates were based on the pathogen group rather than a specific pathogen because of sparse information. We estimated emergency room visits only for waterborne disease outbreaks (WBDOs) in which the number of hospitalizations constituted fewer than 75% of the reported illnesses. For outbreaks where hospitalizations were greater than 75%, we assumed the severity of the illnesses resulted in few cases treated through outpatient services. Both estimates are based upon very few reported values and we were unable to locate peer-reviewed literature for developing comparisons. Thus, these components of the burden estimate are highly uncertain.

Hospitalizations and Deaths

Form CDC 52.12 requests the number of cases hospitalized and deaths occurring during an outbreak. All outbreak reports included an entry for deaths and 659 of the reports (99%) included hospital admission information. Comparison of the WBDOSS data to other infectious disease epidemiologic data available from published literature sources suggests that these data are not significantly over- or under-reported.

EPIDEMIOLOGIC BURDEN ESTIMATES

To examine characteristics that may be associated with the cause of an outbreak and the magnitude of its burden, we analyzed the epidemiologic data by summarization within the following four categories: etiologic agent (i.e., the pathogen), water system type, water system deficiency and water source type. Due to the overwhelming influence of the 1993 Milwaukee cryptosporidiosis outbreak, by far the largest reported in the WBDOSS, we also developed comparisons of the impact of the various factors excluding the data from this event. This outbreak occurred in a community water system that used surface waters as a source of drinking water due to a treatment deficiency and was attributed to the protozoan, *Cryptosporidium*. This outbreak contributed 403,000 (71%) cases of illness, 3,627,000 (81%) person-days ill, 20,280 (48%) physician visits, 11,727 (50%) emergency room visits, 4400 (74%) hospitalizations and 50 (76%) deaths to the estimated epidemiologic burden for all waterborne outbreaks that occurred between 1971-2000.

Epidemiologic Burden by Etiologic Agent

Protozoa, primarily *Cryptosporidium* and *Giardia*, were associated with the most cases, person-days ill, physician visits, emergency room visits, hospitalizations and deaths (Table ES-4). The Milwaukee outbreak accounted for more person-days ill,

TABLE ES-4

Estimated Epidemiologic Burden of Reported Infectious Waterborne Outbreaks in Drinking Water by Etiologic Agent Type, 1971 to 2000*

Etiologic Agent Type	Outbreaks	Cases	Person-Days Ill	Physician Visits	Emergency Room Visits	Hospital-izations	Deaths
AGI	365	83,493	265,000	8,820	9,430	378	1
Viruses	56	15,758	53,700	2,020	124	92	0
Bacteria	101	20,786	95,600	1,200	931	928	15
Protozoa							
Milwaukee WBDO	1	403,000	3,630,000	20,300	11,700	4,400	50
All Other WBDO	142	46,925	463,000	9,700	1,370	117	0
Total	665	569,962	4,500,000	42,000	23,600	5,915	66

* The outbreak, case number, hospitalization and death totals are summarized from WBDOSS. Column totals for person-days ill, physician visits and emergency room visits may not sum due to rounding.

emergency room visits, hospitalizations and deaths than all other outbreaks combined. Excluding the Milwaukee outbreak, protozoan outbreaks still account for more person-days ill and physician visits than outbreaks caused by viruses or bacteria. However, bacterial outbreaks accounted for more hospitalizations when Milwaukee was excluded and 15 of the 16 deaths that were not associated with cryptosporidiosis.

Epidemiologic Burden by Water System

Waterborne outbreaks occurring in community water systems accounted for the most cases (485,844, 85% of total), person-days ill (4,215,965, 93% of total), physician visits (32,400, 77% of total), emergency room visits (16,268, 69% of total), hospitalizations (4931, 83% of total) and deaths (62, 94% of total) that were reported to the WBDOSS. If the Milwaukee outbreak is excluded from the analysis, outbreaks occurring in community systems accounted for 50% of the total non-Milwaukee cases, 67% of the person-days ill, 55% of the physician visits and 75% of the deaths. Outbreaks occurring in non-community systems involved 57% of the total non-Milwaukee emergency room visits and 58% of the hospitalizations. The outbreaks that occurred in individual water systems accounted for no more than 3% of any of the measures when Milwaukee data were included and no more than 7% with Milwaukee excluded.

Epidemiologic Burden by Source Water

Outbreaks in surface water systems were reported less frequently than in groundwater systems but resulted in a greater number of cases (457,310), person-days ill (4,058,221), physician visits (29,735), emergency room visits (14,443), hospitalizations (4644) and deaths (50). Most surface water outbreaks were associated with *Giardia* (48%) or AGI (36%), but most of the person-days ill and deaths in surface water outbreaks were associated with *Cryptosporidium* primarily due to the Milwaukee outbreak. Sixty-two percent (62%) of outbreaks reported in groundwater systems were attributed to AGI and 52% of the person-days ill in groundwater system outbreaks resulted from AGI outbreaks.

Epidemiologic Burden by Water System Deficiency

In comparison to the other water system deficiency issues, outbreaks associated with one or more water treatment deficiencies were responsible for the most of the epidemiologic burden: 92% of the cases, 83% of the person-days ill, 87% of the physician visits, 86% of the ER visits, 84% of the hospitalizations and 79% of the

deaths. Distribution system deficiencies and untreated groundwater accounted for all but about 2% of the remaining burden from each of the severity measures. If the Milwaukee outbreak data are excluded, water treatment deficiencies accounted for 70-75% of the non-Milwaukee cases, person-days ill, physician visits and emergency room visits, but only 38% of the hospitalizations and 13% of the deaths. Distribution system deficiencies were associated with 75% of the non-Milwaukee deaths and 13% of the hospitalizations. Untreated groundwater was the major contributor to the non-Milwaukee hospitalization burden responsible for 40% of the hospital admissions.

MONETARY BURDEN APPROACH

Figure ES-2 shows the components quantified to calculate the monetary burden associated with reported WBDOs. The results of the COI analysis were used to estimate the monetary burden. The COI measures direct and indirect costs. The direct medical costs include medication, physician visits, emergency room visits and hospital stays. Lost productivity, an indirect cost, is estimated based on a fraction of the duration of illness. The COI estimates did not include averting behavior costs or defensive expenditures, costs of epidemiologic investigation or litigation, nor did they consider anxiety, pain and suffering or lost leisure time. We chose not to estimate the monetary burden from mortality. The value of a statistical life (VSL), an approach used by the U.S. EPA to estimate the monetary burden from mortality, is based on estimates of individuals' collective preferences for trade-offs between avoiding premature mortality in the future and wealth. Since the WBDOSS database includes actual deaths reported for waterborne outbreaks, this is inconsistent with a VSL approach.

By using estimated mean values for the morbidity costs, our approach does not capture important sources of cost variability among cases and across different outbreaks. The definitions and calculations are based largely on an economic analysis of the 1993 Milwaukee *Cryptosporidium* outbreak. In the economic burden analysis, we assumed that medical treatment administered and costs for gastrointestinal illnesses have remained constant across years. All cost estimates were updated to 2000 dollars using the Consumer Price Index for various categories of medical care. The CPI is the average change in prices over time for a market basket of goods and services (in this case medical goods and services such as prescription drugs and medical supplies, physicians' services and hospital services) allowing comparisons using constant monetary units.

Because the outbreaks reported in the surveillance system do not identify cases of illness by severity categories of mild, moderate and severe (as used in the

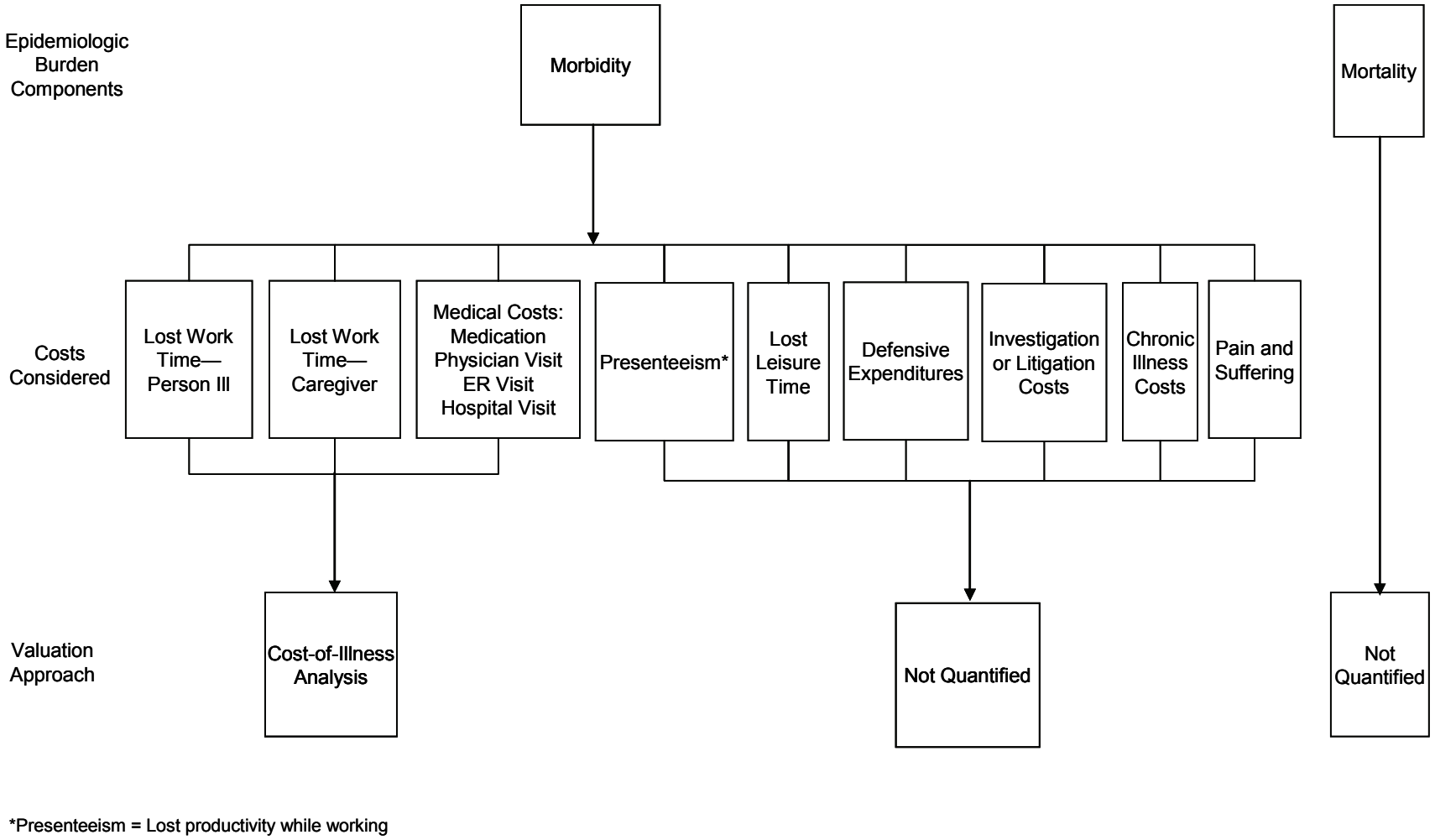


FIGURE ES-2

Illustration of the Components for Monetary Burden Calculations
(Adapted from U.S. EPA, 2000c)

Milwaukee outbreak economic analysis), we used surrogate measures (physician visits and emergency room visits comprised moderately ill cases while hospitalizations and deaths comprised severely ill cases). This introduces additional uncertainty into the COI estimates.

THE MONETARY BURDEN OF WBDOs

The estimated monetary burden (2000$) of the morbidity associated with the outbreaks was approximately $202 million (Table ES-5). The largest morbidity cost was lost productivity of the ill person (61% of the total COI).

TABLE ES-5

Monetary Burden of Infectious Waterborne Outbreaks in Drinking Water, 1971 to 2000

Burden Measure	Monetary Burden* (2000$)	Percent of Total Quantified Monetary Burden
Self-Medication	$1,272,000	1
Physician Visits	$2,708,000	1
Emergency Room Visits	$9,006,000	4
Hospitalizations	$45,652,000	23
Ill Productivity Losses	$123,357,000	61
Caregiver Productivity Losses	$19,721,000	10
Total	$201,716,000	100

* The estimate of monetary burden does not include presenteeism, lost leisure time, pain and suffering, defensive expenditures, investigation or litigation costs, or chronic illness costs (see Figure ES-2).

Monetary Burden Estimate by Etiology

Protozoan agents accounted for most of the monetary burden, and *Cryptosporidium* is the major contributor to the overall monetary burden (78%). Ninety-six percent of the monetary burden associated with *Cryptosporidium* was due to the Milwaukee outbreak.

Monetary Burden by Water System Type and Water Treatment Deficiency

Community systems had the largest monetary disease burden, 13 times larger than the burden associated with non-community systems. Water treatment deficiencies were the most important contributors to the monetary burden. The next two most important contributors were distribution system deficiencies and the use of untreated, contaminated groundwater. If the Milwaukee WBDO is excluded from the analysis, then distribution system deficiencies become the most important contributor to the monetary burden.

SENSITIVITY ANALYSES

We conducted four sensitivity analyses to evaluate key assumptions used to develop the burden estimates and to examine the influence of model input parameters on these estimates.

Sensitivity Analysis 1

We estimated the difference in epidemiologic burden measure needed to cause a 5% change in the total monetary burden. The total monetary burden was most sensitive to differences in the number of person-days ill; a change of 7% in the number of person-days ill changes the total monetary burden by 5%. When the Milwaukee outbreak is excluded, the total monetary burden also was most sensitive to differences in the number person-days ill (7% change required).

Sensitivity Analysis 2

In the second sensitivity analysis, we developed a distribution of the number of deaths associated with each pathogenic agent and for AGI. Using a Monte Carlo approach, the pathogen-specific analysis resulted in a relatively narrow distribution of plausible range of total deaths (88-129) associated with U.S. waterborne outbreaks.

Sensitivity Analysis 3

The third analysis focused on the potential impact of alternative case and duration estimates during the 1993 Milwaukee cryptosporidiosis outbreak, which was responsible for the majority of the monetary burden estimate. The analysis showed that, if a 3-day average duration of illness was used instead of a 9-day duration, then the monetary burden would decrease by approximately one-half. For the 9-day duration, decreasing case estimates by 8% (403,000 vs. 370,000) resulted in total monetary burden estimates that were 8% lower than those based on the reported

values. The same case reductions for the 3-day duration showed 8% lower monetary burden estimates for the Milwaukee WBDO. This further highlights the importance of the contribution of person-days of illness and lost productivity to the monetary burden associated with this outbreak.

Sensitivity Analysis 4

The fourth analysis focused on the impact of a serious sequela on the estimated COI associated with hospitalization costs. Using a range of literature-based estimates for the conditional probability of developing HUS following an *E. coli* gastrointestinal infection, we estimated that from 6-73 HUS cases could have resulted from the *E. coli* drinking water outbreaks. Based on the lower bound of the estimate, the increase in the estimated hospitalization costs associated with *E. coli* outbreaks was approximately 20%. Using the upper bound projection, the hospitalization costs were increased by 145%. Based on the upper bound estimate, the total COI associated with all outbreaks increased by about 1% ($201,716,000). This resulted in an increased COI associated with *E. coli* and *E. coli* and *Campylobacter* outbreaks by 54% ($1.657 million). This highlights the importance of collecting chronic sequela data for outbreaks and shows the potential increase associated with including a sequela from one agent.

CONCLUSIONS

We developed and demonstrated a methodology for assessing the disease burden associated with waterborne outbreaks. Our methodology, which relies on the examination of the waterborne outbreak surveillance data, provides additional insight for evaluating the overall burden of waterborne disease in the U.S. The analyses provide an estimate of the disease burden of reported waterborne outbreaks from the time period 1971-2000. These analyses include an examination of disease severity and some of the costs associated with various waterborne pathogens and water system characteristics. These analyses also helped us identify the limitations of using this passive surveillance system and reinforced the importance of collecting more detailed epidemiologic data to aid future disease burden efforts. We recommend that additional sensitivity analyses be conducted to examine the effect that alternative assumptions might have on the disease burden estimates presented here. This could help identify the components that have the greatest potential impact on disease burden and could further delineate specific research needs for the future.

Although we estimate the burden associated with reported WBDOs, the primary limitation of the analyses was the inability to determine the potential impact of

unrecognized and unreported WBDOs. Additional studies should attempt to estimate the number and type of WBDOs that may be unrecognized. We also provide several recommendations in the collection and reporting of WBDO surveillance data for the purpose of improving future burden estimates.

1. INTRODUCTION

The incidence of devastating waterborne infectious diseases such as cholera and typhoid was dramatically reduced in the United States after filtration and chlorination of drinking water was introduced around 1900. Widespread adoption of these water treatment technologies, along with improved wastewater management, has been among the great public health achievements of the 20th Century (Cutler and Miller, 2005). However, waterborne disease outbreaks (WBDOs) still occur in the U.S. Between 1971 and 2000, the average annual number of drinking water outbreaks reported in the U.S. was 22, with hundreds to thousands of cases of illness attributed to these events every year. Drinking water-related illnesses are likely to occur under non-outbreak (endemic) conditions as well.[1]

The continued occurrence of outbreak and endemic waterborne illnesses motivates examination of quantitative methods to estimate the public health and consequent economic impacts of these illnesses so that regulatory and research strategies can be formulated. These methods should estimate not only the number of waterborne illnesses and their severity but also the monetary costs of these illnesses. Often in the health policy and health economics literature a composite measure of morbidity and mortality—and in some cases, economic impact—is assessed and expressed in a single metric. Such an assessment is frequently referred to as the *burden of disease* (Murray and Lopez, 1996; Gold et al., 1996). In general, burden of disease analyses consist of two steps: a thorough evaluation of the epidemiologic data describing the illnesses and an analysis that evaluates the health effects in terms of their impacts on the ill and society as a whole (Murray and Lopez, 1996). Burden analysis is a necessary component of the economic analysis that has become an integral part of the policy and rule-making process of federal agencies in the U.S. For example, the 1996 amendments to the Safe Drinking Water Act (SDWA)[2] mandate benefit-cost analyses for newly proposed drinking water regulations.

The first step toward evaluating the burden of disease requires estimating the number of cases of the disease that occur in the population under consideration. Currently, three methodological approaches can be used to estimate the amount of waterborne disease that occurs in a population: (1) risk assessment methods that utilize

[1] Approaches to estimate endemic waterborne risks, along with examples of estimates of endemic waterborne illness incidence, are discussed in detail in a special issue of the *Journal of Water and Health,* 2006, Vol. 4 Suppl 2.

[2] SDWA [104/1412(b)(3)(C)] (see http://www.epa.gov/safewater/sdwa/theme.html); Executive Order 12866 (see http://www.whitehouse.gov/omb/inforeg/riaguide.html).

pathogen exposure information and dose-response algorithms (see Text Box 1-1); (2) epidemiologic studies that can be generalized to the larger population (see Calderon and Craun, 2006; Colford et al., 2006; Roy et al., 2006; Messner et al., 2006); and (3) analysis of public health surveillance data. Risk assessment methods have been used by the U.S. Environmental Protection Agency (U.S. EPA) to estimate the current number of cases of endemic waterborne disease (i.e., that which occurs when treatment and distribution systems are functioning according to established practices) for the conduct of economic analyses for new drinking water regulations such as the *Long Term 2 Enhanced Surface Water Treatment Rule* (U.S. EPA, 2005) and the *Ground Water Rule* (U.S. EPA, 2006b).[3] Epidemiologic studies that have been conducted in the U.S. and Canada have been used to inform the SDWA-mandated "national estimate" of waterborne disease (e.g., Colford et al., 2005). This mandate requires the U.S. EPA and the Centers for Disease Control and Prevention (CDC) to jointly conduct pilot epidemiologic waterborne disease occurrence studies in at least five major public water supply systems (U.S. EPA, 1998). But, to date, the third approach described above for estimating waterborne illness occurrence, i.e., using surveillance data, has not been broadly applied to examine the burden of waterborne illness in the U.S.[4]

The purpose of the analyses presented in this document is to investigate the utility of archived WBDO reports[5] as a surveillance-based approach to estimate a portion of the waterborne disease burden. We apply the burden estimation methods described herein to the U.S. WBDOs that occurred between 1971-2000 and were reported to a waterborne disease outbreak surveillance system (WBDOSS) maintained by the CDC and the U.S. EPA (see Section 1.1). It is important to note that limitations inherent in the WBDO reporting system (see Section 1.1.1) preclude estimation of the actual incidence and aggregate burden of outbreak-related waterborne illnesses on a national scale. This analysis of WBDO reports does not attempt to provide an estimate of the actual incidence and burden of outbreak-related waterborne illnesses in the U.S. because such an estimate would require additional data and procedures to estimate unreported outbreaks and unrecognized cases. Unreported outbreaks and cases are not considered in this report. Rather, the purpose here is to explore the potential to develop outbreak disease burden measures from available outbreak surveillance data,

[3] For more details on these water treatment rules, see http://www.epa.gov/safewater/standards.html.
[4] Note that estimates of the burden from single outbreaks—the 1993 Milwaukee cryptosporidiosis outbreak in particular—have been developed, e.g., Corso et al. (2003).
[5] These reports have been voluntarily submitted to the CDC by state and local public health departments.

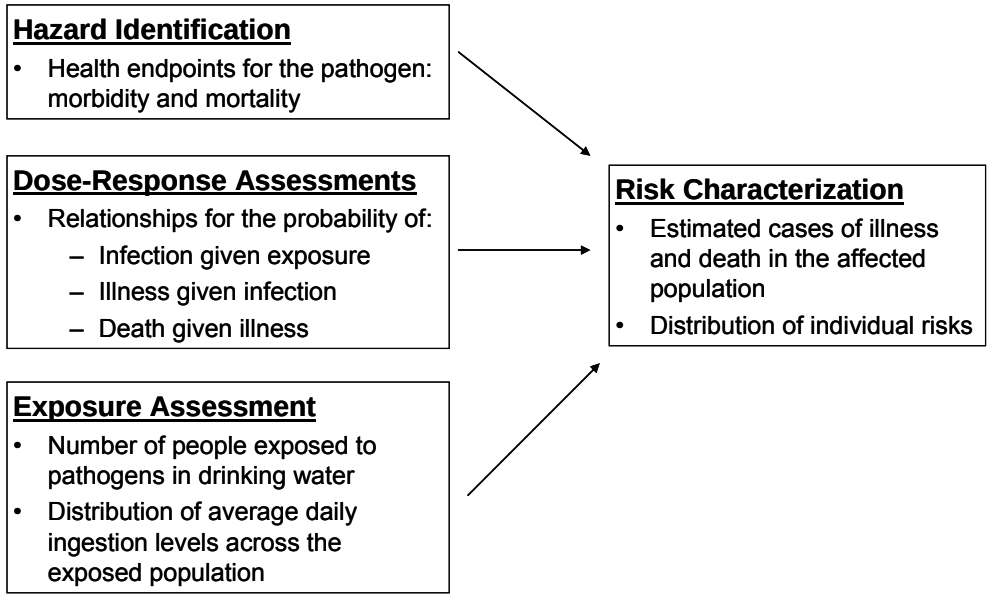
Text Box 1-1. Overview of Risk Assessment Methodology
(Adapted from pp. 5.3-5.5 of the Economic Analysis for the
Final Long Term 2 Enhanced Surface Water Treatment Rule [U.S. EPA, 2005]
and pp. 5.5-5.6 of the Economic Analysis of the Final *Ground Water Rule* [U.S. EPA, 2006c])

Risk assessment is an analytical tool that can be used to characterize the expected incidence of adverse health effects associated with exposure to an environmental hazard. In order to estimate the incidence of endemic illnesses and deaths associated with ingesting infectious microorganisms through drinking water, the U.S. EPA has modeled the incidence of cryptosporidiosis acquired from surface water systems and certain viral infections acquired from groundwater systems. These risk assessments use a standard framework that is organized in accordance with U.S. EPA *Policy for Risk Characterization* (U.S. EPA, 1995a), EPA's *Guidance for Risk Characterization* (U.S. EPA, 1995b), and EPA's *Policy for Use of Probabilistic Analysis in Risk Assessment* (U.S. EPA, 1997b).

This standard framework requires the use of scientific data (or reasonable assumptions if data are not available) to produce estimates of the nature, extent, and degree of a risk. Where there is uncertainty in the data and assumptions used, that uncertainty is described and its impact on the risk estimates is characterized. The microbial risk assessments used by U.S. EPA for drinking water rules incorporate information on variability and uncertainty associated with the data that characterize both the distribution of risk levels within the affected population (variability) and the confidence bounds on key parameters of the risk assessment model (uncertainty). Variability arises from true heterogeneity across people, places and time, and uncertainty represents the lack of knowledge of the true value of the factor being considered (U.S. EPA, 1997b).

According to the 1995 U.S. EPA *Policy for Risk Characterization* (U.S. EPA, 1995a), health risk assessments for environmental contaminants generally involve four components:

- Hazard Identification addresses the nature of the potential adverse health effects associated with exposure to the contaminant.
- Exposure Assessment addresses both the number of people in the population exposed to the contaminant and the distribution of levels of exposure within that population.
- Dose Response Assessment addresses information concerning the relationships, quantitatively where possible, between the magnitude of exposure to the contaminant and the extent and severity of the adverse health effects that may occur.
- Risk Characterization combines the hazard identification, dose-response and exposure assessment information to describe overall risk to the exposed population, both in terms of the distribution of individual risk levels in the population and the total number of cases of adverse effects anticipated.



The diagram depicts the major elements of risk assessments used to characterize the risk of endemic illness (morbidity) and death (mortality) from exposure to microbial pathogens in drinking water systems.

examine the impact of missing information on the resultant burden estimates, and highlight aspects of WBDO-reporting that, if improved or added to the current system, would enhance the potential to develop outbreak burden estimates in the future. The methods developed may provide valuable tools for future U.S. EPA waterborne disease outbreak burden analyses. Similar to the biennial surveillance summaries of waterborne-disease outbreaks published in CDC's *Morbidity and Mortality Weekly Report*, we compare the burden estimates across reported outbreak characteristics including the etiologic agent, type of source water, water treatment system, and attributed deficiency.

1.1. THE WBDO SURVEILLANCE SYSTEM

National statistics on waterborne outbreaks have been compiled and reported in the U.S. since 1920. In 1971, the CDC, the U.S. EPA, and the Council of State and Territorial Epidemiologists began a collaborative, passive surveillance program for the collection of data on the occurrence and causes of waterborne outbreaks. State, territorial, and local public health agencies have the primary responsibility for detecting and investigating waterborne outbreaks, and they voluntarily report them to the CDC on Standard Form 52.12.[6] Two criteria must be met for an event to be defined as a waterborne outbreak (Lee et al., 2002; Blackburn et al., 2004). First, two or more persons must have experienced a similar illness after exposure to water.[7] Second, epidemiologic data must implicate water as the probable source of the illness (see Text Box 1-2).

The standard waterborne outbreak reporting form, which has been used in the U.S. since 1974, solicits data on the characteristics of the outbreak (including the number of ill persons, dates of illness onset, and location that define the outbreak), results from epidemiologic studies, testing of water and patient samples, and contributory issues, such as water distribution, disinfection, and environmental factors. Additional information regarding the water quality, water system and treatment is obtained from the state's drinking water agency as needed. Numerical and text data from the form and supporting documents are entered into the WBDOSS database maintained by the CDC and the U.S. EPA. The purpose of the WBDOSS is to record the data needed to appraise and periodically report the causes of WBDOs (e.g.,

[6] Appendix A shows various forms used during 1971-2002. The current form can be found at www.cdc.gov/healthyswimming/downloads/cdc_5212_waterborne.pdf.

[7] This criterion is waived for single cases of laboratory-confirmed primary amebic meningoencephalitis and for single cases of chemical poisoning if water-quality data indicate contamination by the chemical.

Text Box 1-2. Classification of Investigations of Waterborne-Disease Outbreaks

The CDC and U.S. EPA evaluate reported outbreaks according to the strength of the evidence implicating drinking water as the vehicle of transmission (Lee et al., 2002; Blackburn et al., 2004). The classification scheme is based on both epidemiologic and water-quality data provided by investigators. Although outbreaks without water-quality data are included, those that lack epidemiologic data are not. The classification system was first applied to waterborne outbreaks reported in 1989 (Herwaldt et al., 1991). Before 1989, an informal, similar approach was used to evaluate the evidence.

A waterborne disease outbreak classification of I indicates that adequate epidemiologic and water-quality data were provided to implicate drinking water as the vehicle of infection (see table in this text box). However, "the classification [of I] does not necessarily imply whether an investigation was optimally conducted" (Lee et al., 2002). Neither does a classification of I imply that all information requested on the report form was provided or that it is more complete or accurate than the information provided in an outbreak investigation classified as II, III or IV. The classification of these waterborne outbreaks refers primarily to the adequacy of the epidemiologic information that associates drinking water with illness and whether the supporting engineering and water quality information was provided.

A waterborne disease outbreak classification of II indicates that adequate epidemiologic but inadequate water-quality data were available to implicate drinking water as the vehicle of infection (see table in this text box). A classification of III is indicative of adequate water-quality data but limited epidemiologic data. A classification of II or III should not be interpreted to mean that investigations were inadequate or incomplete. Outbreak investigations occur under various circumstances, and not all outbreaks can be rigorously investigated. In addition, outbreaks that affect few persons are more likely to receive a classification of III or IV, rather than I or II, on the basis of the relatively limited sample size available for statistical analyses (Lee et al., 2002; Blackburn et al., 2004). The surveillance data may include outbreaks with limited epidemiologic evidence of a waterborne association (classifications III or IV) but does not include anecdotal reports of possible waterborne illness (Craun et al., 2001).

Classification of Investigations of Waterborne Disease Outbreaks in the United States

Class	Epidemiologic Data	Water-Quality Data
I	Adequate Data were provided about exposed and unexposed persons, and the relative risk or odds ratio was >2, or the p-value was <0.05	Provided and adequate Historical information or laboratory data (e.g., the history that a chlorinator malfunctioned or a water main broke, no detectable free-chlorine residual, or the presence of coliforms in the water)
II	Adequate	Not provided or inadequate (e.g., laboratory testing of water not done)
III	Provided, but limited Epidemiologic data were provided that did not meet the criteria for Class I, or the claim was made that ill persons had no exposures in common besides water, but no data were provided.	Provided and adequate
IV	Provided, but limited	Not provided or inadequate

etiologic agents, water system deficiencies, and sources of contamination) and the resulting cases of illness. Surveillance summaries of reported waterborne outbreaks have been published annually or biennially since 1973 (CDC, 1973, 1974, 1976a,b, 1977, 1979, 1980, 1981, 1982a,b, 1983, 1984, 1985; St. Louis, 1988; Levine and Craun, 1990; Herwaldt et al., 1991; Moore et al., 1993; Kramer et al., 1996; Levy et al., 1998; Barwick et al., 2000; Lee et al., 2002; Blackburn et al., 2004).

The WBDOSS includes outbreaks associated with drinking water, recreational water, and other types of water exposures. For the analyses in this report, we used information available for drinking water outbreaks that were reported during the 30-year period 1971-2000 and restricted the analysis to those determined or suspected to be of an infectious nature. Recreational water and other non-drinking water outbreaks are not included, nor are drinking water outbreaks attributed to chemical contamination, primary amebic meningoencephalitis, or *Legionella.*

In the 1971-2000 WBDOSS reports used for this analysis the apparent cause of a reported WBDO is classified into one of five water system categories:[8] (1) water treatment deficiency, (2) distribution system deficiency, (3) untreated groundwater, (4) untreated surface water or (5) unknown or miscellaneous deficiency. Water sources are identified as either surface water, groundwater, or mixed (both surface water and groundwater sources). Public drinking water systems are classified as either community or noncommunity based on definitions of the SDWA;[9] private, individual water systems serve families without access to public systems.

1.1.1. Limitations of the Surveillance System and Data. Important limitations of the waterborne outbreak data reported during 1971-2000 include: (1) differences in surveillance intensity and reporting of outbreak occurrence among the states and over time; (2) inconsistencies in the reporting of case numbers, case definitions, and health-related severity information and (3) inadequate information about the etiologic agents. These limitations and their likely effects on a disease burden analysis are summarized in Table 1-1.

1.1.1.1. Inconsistent Reporting of WBDO Occurrence — Because the surveillance is passive and outbreak reporting is voluntary, the WBDOSS data represent only a portion of the waterborne outbreaks that occur in the U.S. Not all

[8] Classifications in the most recent biennial report have been changed (Liang et al., 2006).
[9] Information on public drinking water systems can be accessed at http://www.epa.gov/safewater/pws/index.html.

TABLE 1-1

Important Limitations of the 1971-2000 Waterborne Disease Outbreak Surveillance System (WBDOSS)

Limitation	Consequence
Limitations Affecting the Reporting of Outbreaks	
• Outbreak reporting to the Federal government was voluntary and there were no nationally consistent reporting 'standards' during the 30-year study period	• WBDOSS study data represent only a portion of the outbreaks that occurred in the U.S. during the 30-year study period
• Surveillance was passive and recognition and investigation of outbreaks dependent upon: o public awareness of the outbreak o availability of laboratory testing o local requirements for reporting diseases o resources available to the local health departments o capacities of local public health agencies and laboratories	• Not all outbreaks are detected, especially those that resulted in less serious illness or etiologies that require extensive laboratory testing and have lengthy incubation period • Changes in the number of outbreaks reported could either reflect an actual change in occurrence or change in surveillance sensitivity • Analyses will not include contributions of unrecognized outbreaks to overall burden
Limitations Affecting the Number of Cases and Severity of Illness	
• Case definitions may vary across outbreaks depending upon the signs and symptoms considered important by each investigator	• Number of cases and their severity may not be comparable across outbreaks
• The thoroughness of investigation varies	• Epidemiologic information (e.g., reported or estimated case numbers) may be inconsistent across different outbreaks
• Reporting error, recall bias or other potential epidemiologic biases	• Number of cases may be over- or under-estimated
• Investigators may not provide all of the information requested on CDC 52.12 • Some important severity characteristics (e.g., physician visits, emergency room visits) are not requested on CDC 52.12	• Burden may be underestimated
Limitations Affecting Identification of Etiologic Agent	
• The identification of the etiologic agent depends on: o the capability of the laboratory to test for a particular pathogen o the timely recognition of the outbreak so that appropriate samples can be collected	• Lack of appropriate sampling and analysis relegates classification to "acute gastrointestinal illness of unknown etiology" (AGI) and limits information regarding impact of various etiologic agents
• WBDOs may be retrospectively investigated to identify the etiologic agent and water system deficiencies	• Evidence of contamination may be transitory and no longer available

outbreaks are recognized, investigated or reported to the CDC. Blackburn et al. (2004) suggest that data in the surveillance system underestimate the true incidence of waterborne outbreaks. In part, this is because multiple factors influence whether waterborne outbreaks are recognized and investigated by local or state public health agencies. These include public awareness of the outbreak, availability of laboratory testing, requirements for reporting diseases, and resources available to the local health departments. In addition, the capacity of local and state public health agencies and laboratories to detect an outbreak might influence the numbers of outbreaks reported in each state relative to others. Thus, the states with the majority of outbreaks reported during this period might not be the states where the majority of outbreaks actually occurred. An increase in the number of outbreaks reported could either reflect an actual increase in outbreaks or a change in sensitivity of surveillance practices. As with any passive surveillance system, accuracy of the data depends greatly on the reporting agencies (i.e., state, local and territorial health departments). Thus, independent of the recognition or investigation of a given outbreak, reporting bias can influence the final data. Several estimates have been offered as to the number of waterborne outbreaks that may go unrecognized (Craun, 1986; Hopkins et al., 1985), but additional studies are needed to assess the sensitivity of current surveillance (Blackburn et al., 2004).

Most likely to be recognized and investigated are outbreaks of acute illness characterized by a short incubation period, outbreaks that result in serious illness or symptoms requiring medical treatment, and outbreaks of recently recognized etiologies for which laboratory methods have become more sensitive or widely available (Blackburn et al., 2004). Increased reporting often occurs as the waterborne occurrence of certain etiologic agents becomes better recognized, water system deficiencies are more readily identified, and state surveillance activities and laboratory capabilities increase (Frost et al., 1995, 1996; Hopkins et al., 1985).

1.1.1.2. Inconsistencies in Case Number Estimates and Severity Characterizations — The primary unit of analysis in the WBDOSS is the outbreak, not the individual cases of a waterborne disease. Although case-specific epidemiologic information is not available in the database, information is requested on the outbreak report form about the actual and estimated numbers of cases of illness, cases hospitalized, and fatalities. The report form also requests information about the actual and estimated numbers of persons exposed (at risk), incubation period, duration of illness, the number of patient specimens (e.g., stool, vomitus, serum) examined and laboratory findings.

The case definition will vary among the outbreaks depending upon the suspected etiology and the signs and symptoms that are considered important by each investigator. Form 52.12 requests information about patient histories and the number of persons with various symptoms. The symptoms highlighted on the report form include diarrhea, vomiting, cramps, fever, nausea, rash and conjunctivitis. If a separate investigative report is enclosed, the specific case definition is usually provided. Otherwise, the case definition must be assumed from information provided on the report form. Form 52.12 specifically requests information about the number of persons with diarrhea at a frequency of three stools per day or diarrhea with an alternative definition to be provided by the investigator. The report form also requests information about a confirmed or suspected etiology.

The thoroughness of outbreak reporting varies, and the epidemiologic information (e.g., population exposed, attack rates, cases and severity of illness) may be inconsistent or sparse across different waterborne outbreaks. Cases of illness may be over- or under-estimated due to recall or other epidemiologic biases or inadequate information about the estimated size of the exposed population (Craun and Frost, 2002; Craun et al., 2001). The Milwaukee cryptosporidiosis outbreak investigation exemplifies a particularly in-depth effort to estimate the number of cases of illness and their severity (Mac Kenzie et al., 1994; Hoxie et al., 1997; Naumova et al., 2003; Proctor et al., 1998; McDonald et al., 2001). However, even after extensive investigation, there is still uncertainty about the outbreak's overall impact on Milwaukee residents. Hunter and Syed (2001) suggest that cases attributed to the waterborne outbreak were greatly overestimated, while a study of *Cryptosporidium*-specific antibody responses in children by McDonald et al. (2001) indicates that infection was much more widespread than previously appreciated. However, McDonald et al. provided no information about symptoms or severity of cryptosporidiosis in the infected children which would allow for corroboration of these serologic data.

The information requested on the standard report form can help describe the cases associated with a specific outbreak, but investigators may not provide complete information about all of the measures that are considered important for estimating the public health and economic impact of the outbreak. The primary purpose of an investigation is to identify the cause of the outbreak so that steps can be taken to stop the outbreak, and this presumes that the recognition of a WBDO is timely. If water is implicated in an outbreak investigation where cases are continuing to occur, the focus will be on understanding the circumstances that led to the outbreak and developing corrective measures to ensure that the water is safe. In addition, WBDOs may be

retrospectively investigated to identify the etiologic agent and water system deficiencies. In this case, limited information may be available to the investigator. Thus, identification of all of the factors that contribute to the ultimate impact of the WBDO may be of secondary importance, depending on the suspected etiology, population at risk, and available resources. Furthermore, illnesses among travelers and tourists may be geographically dispersed making it difficult to recognize all cases. Recurring methodological problems may also limit the information about waterborne transmission. For example, an outbreak may impact relatively few persons making it difficult to identify a waterborne association, or there may be a large number of persons with asymptomatic infections or mild illnesses that are not identified because health care consultation or treatment was not sought.

Not all WBDO investigations identify both primary and secondary cases to assess the full impact of the outbreak. Primary cases are persons who are exposed to and infected by contaminated water; secondary cases are persons who are infected by and became ill after contact with primary case-patients. Primary cases can readily be a source of secondary infections, since some waterborne pathogens are easily spread by person-to-person transmission (Craun et al., 2001). The standard report form does not distinguish between primary and secondary cases. If primary cases and secondary cases are noted in the remarks section of the report form or separate reports, only primary cases are included in the WBDOSS; if no distinction was made, we assume all reported cases to be primary.

1.1.1.3. Incomplete Information Regarding Etiology of Outbreaks — Another limitation of the WBDOSS is the lack of information about the etiology of reported outbreaks. During the 30-year surveillance period, an etiologic agent was not identified in 55% of the reported waterborne outbreaks of infectious disease. The identification of the etiologic agent depends on the capability of the laboratory to test for a particular pathogen and timely recognition of the outbreak so that appropriate samples can be collected. Routine testing of stool specimens includes tests for the presence of enteric bacterial pathogens and might also include an ova and parasite examination. However, *Cryptosporidium*, among the most commonly reported waterborne pathogens, is often not included in standard ova and parasite examinations (Lee et al., 2002). Although norovirus testing is now performed more frequently, testing in the past has been infrequent or unavailable and testing for other viral agents is rarely done in waterborne outbreaks (Blackburn et al., 2004). The waterborne outbreaks of undetermined gastroenteritis are considered as a single entity for the analyses in this report. The

outbreaks in this group could have been caused by various viral, bacterial or protozoan pathogens.

1.1.1.4. Additional Concerns — Because of improvements in drinking water monitoring, treatment, and operation during the 30-year period, as well as changes in demographics and land use, there are likely to be differences over time as to the contribution of certain etiologic agents or water system deficiencies to outbreak frequency. Thus, the information in this report should be cautiously interpreted in terms of waterborne risks that may occur in the future. We again emphasize that this WBDO burden analysis is intended to identify limitations of the illness severity and case number information available from previously reported outbreaks.

1.2. MEASURES OF THE BURDEN OF DISEASE

Although traditional epidemiologic measures, such as age-standardized mortality rates, provide a sense of the relative health of one group of people compared to another, in many cases they are inadequate for the public health decision-making needs of contemporary communities and governments (CDC, 2005; Gold et al., 1996; Murray and Lopez, 1996). Advances in public health and sanitation have brought about such great increases in life expectancy in developed countries that new methods to evaluate public health consider the quality of life as well as the length of life. Quality-of-life issues, from a public health perspective, include the severity and duration of the illness, injury, or disability; pain and suffering; and the physical, psychological and social impacts of poor health. When a WBDO occurs, individuals and communities incur both health and economic impacts. The health impacts can include a broad range of effects from the very mild (such as brief episodes of diarrhea in healthy adults) to severe (such as dehydrating and life-threatening diarrhea in infants or the immunocompromised). The economic impacts, from an individual's point of view (i.e., model of consumer welfare) can include the costs associated with treatment of the ill as well as lost productivity at work or home. While a variety of measures, such as Quality Adjusted

Life Years (QALYs) or Disability Adjusted Life Years (DALYs)[10] have been employed to estimate disease burden in other studies (Murray and Lopez, 1996; Havelaar et al., 2000; Pruss et al., 2002), we limit the measures used for this analysis to the benefits assessment measures currently employed in U.S. EPA-rulemaking procedures (U.S. EPA, 2000a, 2006a,b).[11]

1.2.1. EPA Benefits Assessment Measures. Standard U.S. EPA practice for economic analyses to support environmental decision-making is based on the principles of welfare economics[12] (U.S. EPA, 2000a). Willingness-to-pay (WTP) measures, which reflect the monetary value that individuals place on implementing an action or program, are consistent with those principles (Freeman, 1993). WTP can be estimated from surveys of individuals' stated preferences[13] or by analyzing preferences revealed by examination of primary "observable" data.[14] For example, in the public health realm, this could include the WTP for a technology or intervention that reduces the risk of contracting future illnesses.

[10] QALYs and DALYs are summary population health measures that attempt to integrate the burden of premature mortality with the burden of decreased quality of life associated with various morbidities. For these measures, the impact of a disease on an afflicted individual is assessed by a utility weight using a scale of 0 to 1. For QALYs, a utility weight of 1 indicates perfect health and a utility weight of 0 indicates death. For DALYs, the scale is reversed: utility weight of 0 indicates perfect health (i.e., no disability) and utility weights close to 1 indicate poor health. Cost-effectiveness analyses describe the increase in QALYs or decrease in DALYs per dollar allocated for risk reduction. QALYs were originally developed to assist in health care resource allocation decisions. These are commonly used to examine the effectiveness of medical interventions. A year in perfect health equals 1 QALY. When decision-makers use QALYs to evaluate alternative health care policies, they sum the QALYs experienced by affected individuals. DALYs combine information on the burden of premature mortality (in terms of years of life lost) with preferences for quantitative changes in the quality of life associated with morbid conditions. DALYs are the sum of years of life lost and years lived with disability (Murray and Lopez, 1996). DALYs were developed as a systematic method for estimating morbidity and mortality impacts across different countries and regions of the world (Murray and Lopez, 1996).

[11] Epidemiologic data frequently serve to describe disease incidence and prevalence for the more extensively reported infectious diseases, chronic diseases and injuries that are typically evaluated in disease burden studies. However, limited data on gastrointestinal infections has motivated U.S. EPA, for most applications to date, to use risk assessment methods to generate disease incidence estimates.

[12] "Welfare economics" refers to a branch of economic theory that holds that individuals (rather than elected or appointed decision makers) are the best judges of their own welfare. The basis of welfare economics lies in the premise that social welfare should be comprised of individuals' welfare and that these individuals collectively provide the best information on social welfare issues. It is assumed that resource allocation is appropriately driven by competitive market forces.

[13] To determine the benefits of controlling freshwater pollution, Mitchell and Carson (1989) asked American households to value water quality improvements for the U.S.; Viscusi and Aldy (2003) summarized the results of a group of studies in which people were asked if they would pay a certain dollar amount to avoid a specified increased risk of premature death.

[14] For example, to estimate the WTP to avoid giardiasis during an outbreak, Harrington et al. (1989) examined the costs of hauling safe water, boiling water, purchasing bottled water, and expenditures on water filters and purifiers, sometimes referred to as averting behavior.

WTP functions as an *ex ante*[15] measure because the value of reducing the risk of contracting an illness is, in many cases, decided *before* the risk is incurred. WTP would measure the trade-off between health risk and wealth based on an individual's preferences (Freeman, 1993; Hammitt, 2002). WTP can include valuation of medical and non-medical costs (e.g., expenditures for preventative measures, travel time), lost wages due to the disease, pain and suffering, and premature death (U.S. EPA, 1999, 2000a, 2002). WTP is generally considered a more comprehensive measure of total value for avoiding an illness than other economic metrics such as cost-of-illness (COI).[16]

An alternative to collecting primary WTP data via observation or survey is to use benefit transfer based on secondary data. Benefit transfer applies WTP information from one study to another location or context (Desvousges et al., 1992). The accuracy of benefit transfer depends on the existence and quality of applicable studies. The advantages of benefit transfer approaches include saving the time and cost of developing and implementing new studies. The U.S. EPA typically transfers WTP estimates to support environmental decision-making because of limitations on primary data collection with surveys (see The Paper Reduction Act of 1995). However, information regarding the WTP to avoid gastroenteritis morbidity is not readily available for benefit transfer (e.g., only a few original studies like Harrington et al. [1989] exist). Therefore, as is U.S. EPA practice when few WTP studies exist, estimates based on a COI approach are substituted and transferred as an approximation for the WTP to avoid morbidity.

1.2.2. The Monetary Burden of Morbidity – The Cost-of-Illness Approach. For this WBDO analysis, we have employed data derived from several peer-reviewed sources that provide COI estimates specifically for waterborne outbreaks (e.g., Corso et al., 2003; Harrington et al., 1991). The COI is a human capital approach (i.e., quantifiable in terms of market-place productivity) that is based on measured *ex post* (i.e., known and certain) costs associated with disease (U.S. EPA, 1999, 2000a, 2002; see discussion in Drummond et al., 2000). In this approach, costs are divided into direct costs, which include the market value estimates of treatment costs (e.g., the costs of medication, physician visits, emergency room visits, and hospitalization for infectious diseases), and indirect costs (e.g., lost productivity in the workplace and at home due to

[15] *Ex ante*, literally translates from Latin as "beforehand." In economic models the *ex ante* values (e.g., of expected gain) are those that are calculated before there is certainty of the outcome.
[16] U.S. EPA (2000a) states that WTP estimates could underestimate the social costs because they may not capture health care costs paid by insurance companies, hospitals, or employers (e.g., sick leave).

morbidity). Although premature death can also be considered an indirect cost when evaluated as lost productivity, a COI approach for mortality valuation is not standard U.S. EPA practice. The COI approach for valuing morbidity provides information on the monetary impact of an outbreak but not necessarily on the severity of the impact (Kuchler and Golan, 1999). COI approaches do not completely capture the impact of an outbreak from a societal valuation perspective, because they do not measure individual preferences for avoiding pain and suffering, averting costs, anxiety, or risk attitudes (U.S. EPA, 2000a).

1.2.3. Consideration of Deaths. Standard U.S. EPA practice for estimating the monetary burden associated with mortality involves using the "value of a statistical life" (VSL). The VSL is an approach for determining the economic value of reducing the risk of premature death. It is an aggregate measure of individuals' WTP to avoid a small change in the risk of dying (Hammitt, 2000; U.S. EPA, 2000a).[17] However, the deaths considered in this report are deaths that actually occurred (not hypothetical or *ex ante* risk). The VSL is not an appropriate measure for the burden evaluation of actual deaths. In addition, substituting the COI approach to estimate the burden of premature deaths is not standard U.S. EPA practice. We, therefore, only consider here the *number* of deaths reported and include a sensitivity analysis of that number. An estimate of the monetary burden of the deaths due to WBDOs is not provided.

1.3. OBJECTIVES

The objective of this report is to demonstrate an approach for developing a burden of disease estimate that is based on public health surveillance data. To achieve this objective, we use the reported information in the WBDOSS to develop a preliminary estimate[18] of the infectious disease burden associated with the illnesses recorded in the WBDOSS for outbreaks that occurred over the 30-year period of 1971 through 2000. We compared these burden estimates across various water system and outbreak characteristics including etiologic agent, etiologic agent type, source water type, water system type and system deficiency. We emphasize that these burden estimates do not necessarily represent current or future infectious waterborne disease risks or an

[17] Essentially, the VSL is used to represent the benefit of avoiding one generic individual's premature death, rather than that of an identified individual (see Hammitt [2002] for a theoretical discussion).
[18] The estimate is considered preliminary because it is based solely on outbreaks (and the cases of illness within those outbreaks) that are reported to the WBDO surveillance system. A comprehensive assessment would require estimates of both the unrecognized outbreaks and unreported cases as well as an assessment of possible over-estimates of cases in the surveillance system. These additional levels of analysis are not provided in this report.

estimate of the aggregate burden. These analyses are intended to demonstrate the potential to develop integrative burden measures based on surveillance data that may prove useful for planning a research agenda and public health decision-making. The burden estimates do not include endemic (i.e., sporadic) cases of waterborne illness unrelated to outbreak events nor do they include cases of acute chemical poisonings associated with drinking water.

Methods were devised to estimate necessary values for incompletely reported information in the database (see Chapter 2). Epidemiologic and monetary measures are provided here for burden estimation. The epidemiologic measures, which were essential for developing the monetary burden, include the following components:

- Cases of illness
- Duration of illness
- Physician visits
- Emergency room visits
- Hospitalizations
- Deaths.

Given the discussion above, the monetary measures based on COI consider the following:

- Cost of medical care
- Cost of prescribed medication and self-medication
- Productivity losses at work and home.

The approach used in this report is illustrated in Figure 1-1.

1.3.1. Components of the WBDO Burden Analysis. We begin the burden analysis by presenting the reported epidemiologic data in Chapter 2. If sufficient information is not available directly from the WBDOSS, then data gaps are addressed in two ways:

1. Much of the information used to supplement the database gaps is obtained from related data recorded in the WBDOSS database itself (e.g., information from a different waterborne outbreak caused by the same or a similar etiologic agent).

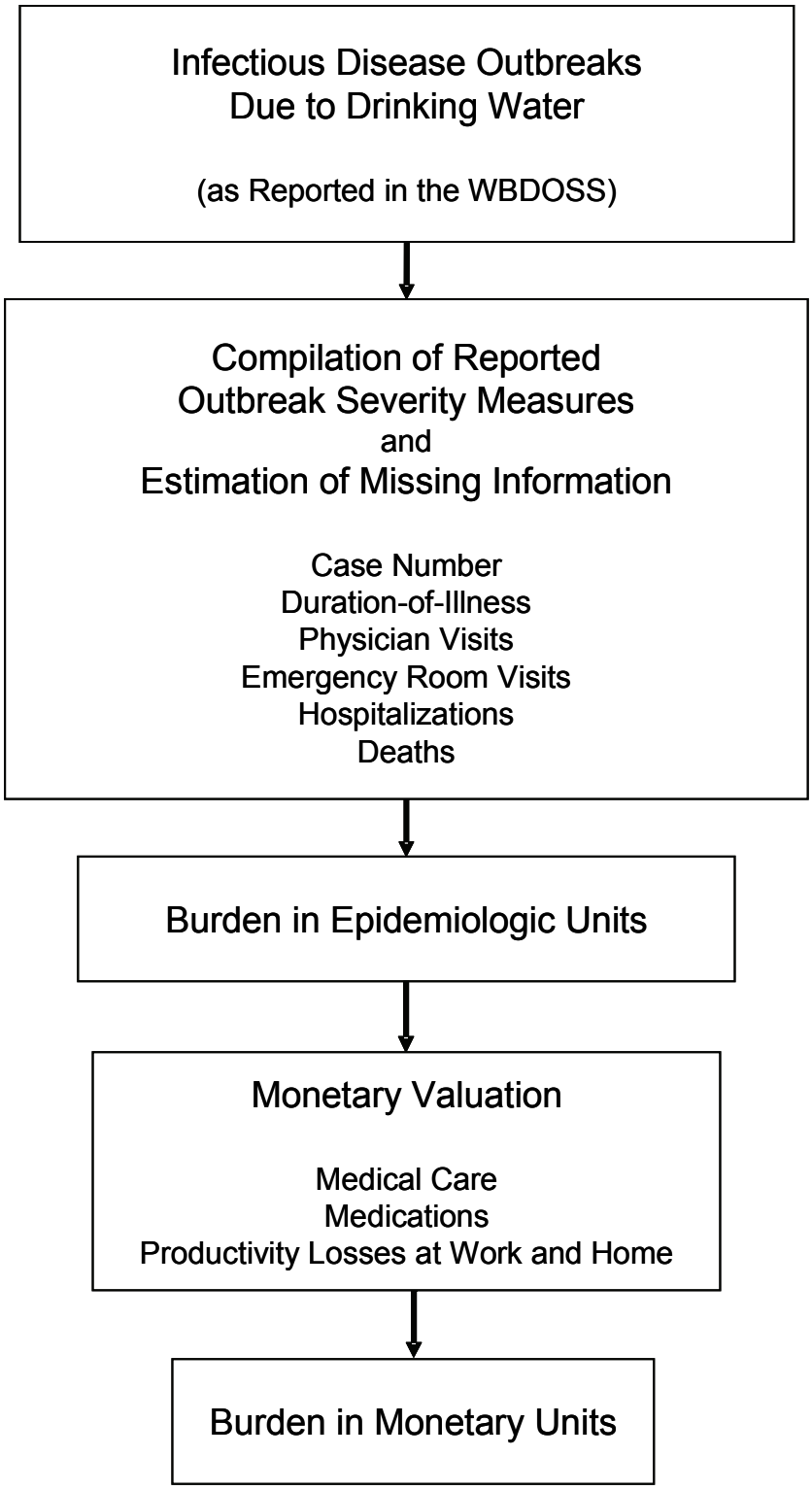


FIGURE 1-1
Methodology to Determine the Disease Burden of WBDOs

2. When the information in the database cannot meet that need, information is obtained from the scientific and medical peer-reviewed literature.

Chapter 3 compares WBDO disease burden estimates (in epidemiologic units) across etiologic agents, source water types, deficiencies and other outbreak characteristics. It is important to note that the quantified epidemiologic burden presented in this chapter describes only a subset of the total epidemiologic burden associated with waterborne outbreaks. Chapter 4 provides the methods used to develop the monetary burden. In Chapter 5, we compare the monetary measures of disease burden estimates across etiologic agents, source water types, deficiencies and other outbreak characteristics. It is important to note that the monetary burden quantified in this chapter also describes only a subset of the total monetary burden associated with waterborne outbreaks. Chapter 6 presents four separate sensitivity analyses; these analyses highlight the potential impacts of some of the uncertainties on the monetary burden. The results, conclusions and research needs are discussed in Chapter 7. Samples of CDC 52.12 and additional discussion of the database are provided in Appendix A. Appendix B categorizes the WBDOs by outbreak investigation method. The waterborne disease outbreak burden between 1971 and 2000 is summarized for each etiologic agent in Appendix C.

2. MEASURES AND METHODS FOR ESTIMATING THE EPIDEMIOLOGIC IMPACTS OF INFECTIOUS DISEASE OUTBREAKS ASSOCIATED WITH DRINKING WATER

The epidemiologic impact of the infectious disease outbreaks that were reported to the WBDOSS during the 30-year period from 1971-2000 was evaluated by the following measures of outbreak severity:[1]

- Cases of illness
- Duration of illness (used to compute person-days of illness, i.e., duration of illness × number of cases of illness)
- Physician visits
- Emergency room visits
- Hospitalizations
- Deaths

The measures listed above were not fully reported in the WBDOSS for all of the 665 outbreaks on record. The number of illnesses and number of deaths were reported for all of the outbreaks, hospitalization information was included in all but six of the reports and duration of illness was provided for only 282 of the outbreaks (Table 2-1). Physician visits and emergency room visits are not specifically requested on the standard waterborne diseases outbreak reporting form CDC 52.12. The number of physician visits or emergency room visits was available only when local outbreak investigators provided that information in supplemental reports (Table 2-1). Twenty-nine (29) outbreak reports included physician visit data and 15 included emergency room visit data.

Since health care utilization data in the WBDOSS are usually reported as summaries rather than individual medical care histories, we could not develop mutually exclusive categories for the severity measures. The reported categories do not distinguish between individuals who seek the same level of health care once or multiple times. The same individual could appear in multiple categories; for example, an individual who visited the emergency room and was then hospitalized, counts towards two different severity measures in the same outbreak. Finally, based on information

[1] Here "severity measure" is a generic term that describes the outbreak impact in terms of how many people were affected, how long their illnesses lasted, what medical services they utilized, and whether or not the outbreak lead to any deaths.

TABLE 2-1

Availability of Selected Severity Measures in the Waterborne Disease Outbreak (WBDO) Surveillance System (Number of Infectious or Suspected Infectious Drinking Water Outbreaks = 665)

Severity Measure	WBDOs for Which Severity Measure was Reported			Does CDC 52.12 Request this Measure?
	Number	Percent	Reports with Entry of "Zero"	
Cases of Illness*	665	100	none	Yes
Duration of illness	282	42	none	Yes
Hospital admissions	659	99	469	Yes
Physician visits	29	4	NA	No
Emergency room visits	15	2	NA	No
Deaths	665	100	659	Yes

*Cases of illness are either actual case counts or an estimate of the number of illnesses. We use whichever was reported to the WBDOSS.
NA = not applicable because number was not requested on CDC 52.12

reported in the WBDOSS, it is difficult to know whether persons who died and were included in the "deaths" category had also been hospitalized.

In this chapter, the epidemiologic components are summarized according to the pathogen identified as the etiologic agent of the outbreak. CDC 52.12 requests laboratory findings for patient specimens (e.g., stool), and, consequently, 300 of the 665 outbreaks were attributed to specific waterborne pathogens identified by laboratory analysis. The other 365 outbreaks were identified as "acute gastrointestinal illness of unknown etiology" (AGI) either because laboratory results were not available or an etiologic agent could not be identified by the tests performed.

2.1. METHODS FOR ESTIMATING MISSING SEVERITY INFORMATION

If data regarding duration of illness, physician visit or emergency room use was not provided in a WBDO report, we estimated values for the missing data. Methods for developing these estimates are described within each severity category section below. Briefly, missing duration of illness values were derived from other WBDOs reported for the same etiologic agent if six or more of such reports were available from the WBDOSS. If fewer than six reports for the same agent were available, external literature sources were used (Method detailed in Figure 2-1). Missing physician visit and emergency room rates were estimated from a representative agent of the same class (i.e., viral, bacterial, or protozoan) in the WBDOSS. Almost all reports included case number (100%), hospitalization data (99%), and death information (100%) so there are no estimated values for these three severity measures.

2.2. CASES OF ILLNESS

CDC 52.12 requests information about the number of actual and estimated cases. In the majority of WBDOs (70%), cases of illness were reported as an actual count rather than an estimate. The case numbers presented in this analysis are the numbers as reported in the WBDOSS. The number of reported outbreaks attributed to each particular etiologic agent or classed as "AGI" and the total number of reported cases in each category are provided in the second and third columns of Table 2-2.

The actual case counts included illnesses reported to the local public health agency or to the local WBDO investigators by physicians, ill persons or clinical laboratories. When local outbreak investigators reported an estimated number of cases, they might have conducted a survey of randomly selected persons in an affected area or a survey of physicians; however, the method used to estimate cases is not requested or provided on CDC 52.12. The Mac Kenzie et al. (1994) investigation of the

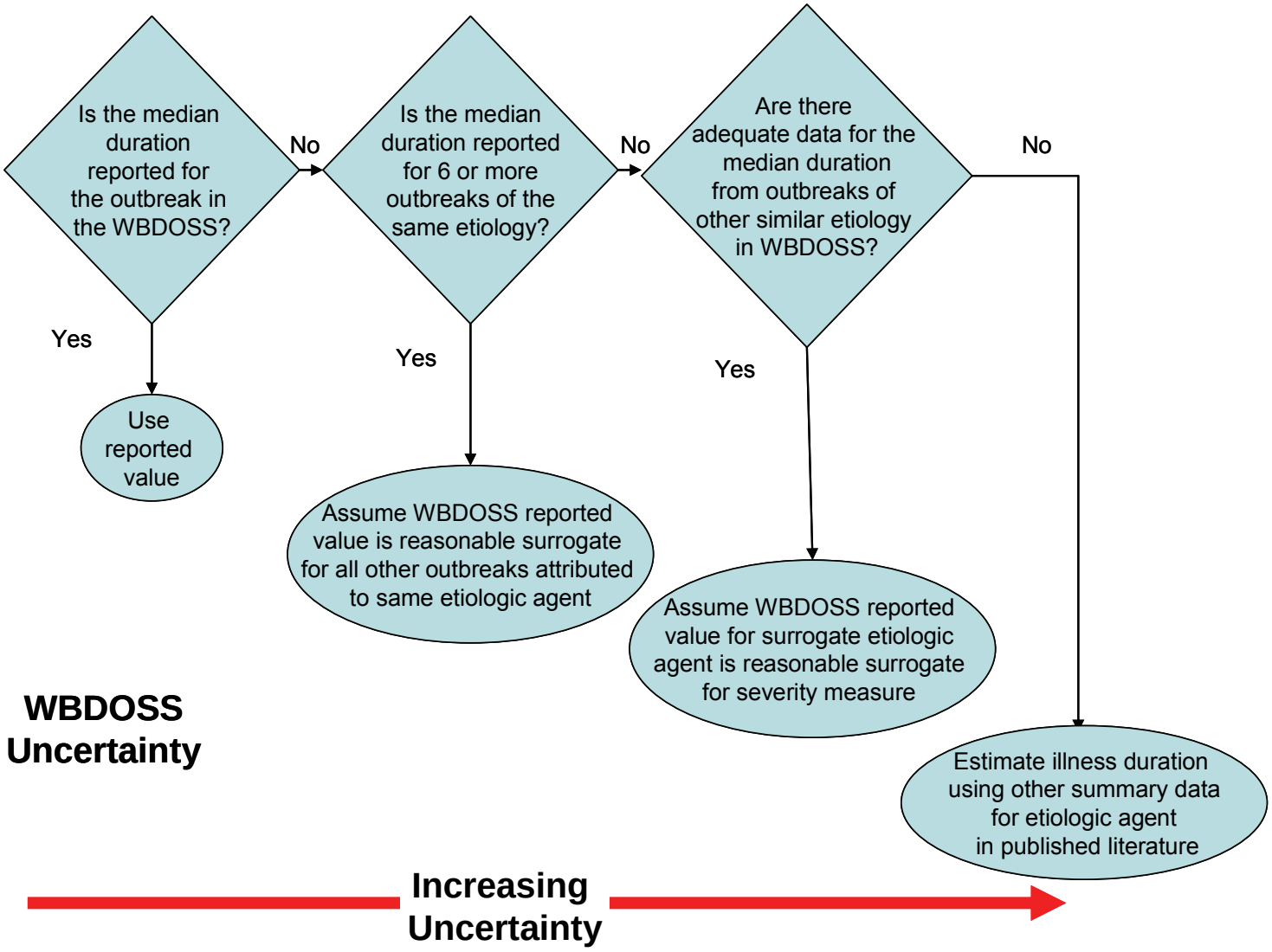


FIGURE 2-1

Method Used to Estimate Illness Duration for WBDOs

TABLE 2-2

Durations of Illness (in Days) by Etiologic Agent, WBDOs, 1971 to 2000

Etiologic Agent	All WBDOSS Outbreaks		Outbreaks Reporting Median Durations of Illness					Estimated Durations for WBDOs without WBDOSS Duration Records	
	Out-breaks	Cases	Out-breaks	Cases	Min-Max (days)	Median of Reported Median Durations (days)	Mean of Reported Median Durations (95% CI)[a] (days)	Mean, Median, or Midpoint (range) (days)	Source
AGI	365	83,493	189	56,401	0.1-60	2	4.2 (3.7-4.9)	4.2	AGI mean from WBDOSS
Viruses									
Norovirus	26	13,100	16	5,870	1-4	1.75	2 (1.1-3.2)	2	Norovirus mean, WBDOSS
SRSV (assumed to be norovirus)	1	70	1	70	2-2	2	–	2	Norovirus mean, WBDOSS
Rotavirus	1	1,761	0	0	–	–	–	5.5 (3-8)	CDC fact sheet[b]
Hepatitis A	28	827	2	45	26-60	43	43 (5.2-155.2)	21	Ciocca (2000)

TABLE 2-2 cont.

Etiologic Agent	All WBDOSS Outbreaks		Outbreaks Reporting Median Durations of Illness					Estimated Durations for WBDOs without WBDOSS Duration Records	
	Out-breaks	Cases	Out-breaks	Cases	Min-Max (days)	Median of Reported Median Durations (days)	Mean of Reported Median Durations (95% CI)[a] (days)	Mean, Median, or Midpoint (range) (days)	Source
Bacteria									
Campylobacter jejuni	19	5,604	8	4,285	2-6	4.8	4.4 (1.9-8.6)	4.4	*C. jejuni* mean, WBDOSS
Escherichia coli O157:H7 & other[c]	12	1,529	7	1,310	3-9.3	4.3	5.3 (2.1-11)	5.3	*E. coli* mean, WBDOSS
E. coli O157:H7 *& Campylobacter*	1	781	0	0	–	–	–	4.8	Bacterial mean, WBDOSS
Plesiomonas shigelloides	1	60	0	0	–	–	–	4.8	Bacterial mean, WBDOSS
Salmonella, non-typhoid spp.	15	3,203	5	949	2-5	4	3.9 (1.3-9)	6 (4-7)[d]	CDC fact sheet[d]
Salmonella enterica serovar Typhi	5	282	1	60	14-14	14	14.0 (0.4-78)	21	CDC fact sheet[e]
Shigella	44	9,196	11	4,246	1.5-7	3.3	3.8 (1.9-6.7)	3.8	*Shigella* mean, WBDOSS
Vibrio cholerae	2	28	0	0	–	–	–	4.8	Bacterial mean, WBDOSS

TABLE 2-2 cont.

Etiologic Agent	All WBDOSS Outbreaks		Outbreaks Reporting Median Durations of Illness					Estimated Durations for WBDOs without WBDOSS Duration Records	
	Out-breaks	Cases	Out-breaks	Cases	Min-Max (days)	Median of Reported Median Durations (days)	Mean of Reported Median Durations (95% CI)[a] (days)	Mean, Median, or Midpoint (range) (days)	Source
Yersinia	2	103	2	103	5-10	7.5	7.5 (0.9-27.1)	7.5	*Yersinia* mean, WBDOSS
Protozoa									
Cryptosporidium	15	421,473	12	408,312	3-74	8.8	18.6 (9.6-32.5)	8.8	*Cryptopsoridium* median, WBDOSS
Cyclospora	1	21	0	0	–	–	–	10 (few-30)	Herwaldt (2000)
Entamoeba histolytica	1	4	0	0	–	–	–	15 (several weeks)	Stanley (2003)
Giardia	126	28,427	28	13,191	0.6-41	12	12.7 (8.4-18.4)	12.7	*Giardia* mean, WBDOSS
Total	665	569,962	282	494,842					

[a] 95% confidence intervals estimated based on the median duration value reported for each outbreak (Schoenberg, 1983).
[b] http://www.cdc.gov/ncidod/dvrd/revb/gastro/rotavirus.htm
[c] One outbreak was attributed to *E. coli* O6:H16; the remaining outbreaks were attributed to strain O157:H7.
[d] http://www.cdc.gov/ncidod/dbmd/diseaseinfo/salmonellosis_g.htm
[e] http://www.cdc.gov/ncidod/dbmd/diseaseinfo/typhoidfever_t.htm
SRSV = Small round structured virus

Milwaukee *Cryptosporidium* outbreak that occurred in 1993 provides a case-number estimation example. For this investigation, an extensive search was undertaken to identify the cases of gastrointestinal disease, the types of symptoms, the numbers of physician visits, and hospitalizations associated with this outbreak. Investigators identified 285 laboratory-confirmed cases of cryptosporidiosis, and 93% of those cases experienced diarrhea that they characterized as "watery." Another 235 cases of diarrhea experienced during the outbreak time frame (March 1-April 28, 1993) were identified through a telephone survey conducted to identify the clinical symptoms of cryptosporidiosis. Two hundred one (201) of the respondents (86%) reported watery diarrhea symptoms. Subsequently, "watery diarrhea" was the case definition used for further case incidence estimation. The number of additional cases attributable to the outbreak was then estimated by means of a second telephone survey of 613 households throughout the greater Milwaukee area. Investigators found that 493 (26%) of the 1663 household members surveyed reported experiencing watery diarrhea at some point during the outbreak time frame. By applying the proportion of survey respondents experiencing watery diarrhea (26%) to the total population at risk (1.61 million people), investigators estimated that 419,000 persons may have been ill with diarrhea during the Milwaukee WBDO. Subtracting a background rate of 0.5% per month (16,000 people) for diarrhea due to causes other than cryptosporidiosis (Mac Kenzie et al., 1994), an estimated 403,000 people had watery diarrhea that could be attributed to the *Cryptosporidium* outbreak, and it is this number that is reported in the WBDOSS.

2.3. DURATION OF ILLNESS

Duration of illness measures the length of time that an individual experiences symptoms associated with an infection. The shortest, longest, median, and mean durations of illness are requested on CDC 52.12. For our analyses, we typically use the value of the median provided on the form. To compute the composite measure "person-days ill", we multiplied the central tendency estimate of the duration of a particular illness by the number of persons who experienced that illness (i.e., number of cases). The person-days ill metric provides a succinct way to compare the population-level health impact of different waterborne diseases, assuming that the symptoms associated with various outbreaks are comparable. For example, for gastrointestinal illnesses, the public health impact of a norovirus (2-day typical duration of gastrointestinal illness) outbreak of 50 cases could be compared to the public health impact of a *Giardia* (12-day typical duration of gastrointestinal illness) outbreak of eight cases: 100 person-

days ill for the norovirus outbreak, 96 person-days ill for the *Giardia* outbreak. The person-days ill measure is an important component of the summaries developed in Chapter 3.

Overall, the duration of illness characteristic of an outbreak was reported for 282 of the 665 WBDOs in the database. Figure 2-1 illustrates the methods used to develop estimates for duration of illness for the 383 outbreaks in which these data were missing from the reports. When duration of illness data were not reported, we initially determined whether six or more outbreaks attributed to the same etiologic agent reported a central tendency estimate of duration of illness. If such data were not available, then illness duration data from WBDOs attributed to similar etiologic agents or values from the literature were sought. Figure 2-1 also highlights two types of uncertainties. For the outbreaks that reported duration of illness information, there are uncertainties attributable to the WBDOSS database (described in Chapter 1). The use of surrogate information to develop duration of illness estimates for WBDOs missing such data is an additional source of uncertainty. Table 2-2 provides reported and estimated duration of illness values. For most etiologic agents, the overall mean of the median durations of illness and the overall median of the median durations of illness were similar. The primary source of information for missing values is the mean of the median durations of illness reported for other WBDOs of the same or similar etiology. For example, median duration of illness was reported for 28 of the 126 *Giardia* WBDOs in the database. The mean of these 28 values (12.7 days) was used as an estimate for the other 98 *Giardia* WBDO reports that did not include an entry for duration of illness. We note that the median value was consistent with ranges reported by other authors and summarized in Table 2-3. However, for *Cryptosporidium* outbreaks, the mean duration of illness value reported for 11 of the outbreaks was considerably greater than the median due to extremely long median duration of illness reported for two of them (i.e., 60 days and 74 days). The median duration of illness of the 11 outbreaks of cryptosporidiosis (8.8 days) was used for the burden analysis because this more closely corresponds to the duration of 1-2 weeks reported in the CDC fact sheet for cryptosporidiosis (http://www.dpd.cdc.gov/dpdx/HTML/Cryptosporidiosis.htm). The duration estimate of 8.8 days for cryptosporidiosis is within the ranges reported by other authors summarized in Table 2-3.

The durations of illness estimates for Hepatitis A, non-typhoid *Salmonella* spp., *S. enterica* serovar Typhi, *Entamoeba histolytica, Cyclospora*, and rotavirus are based on other literature sources (see Table 2-2 footnotes and references). As noted in Figure 2-1, use of such data is associated with additional uncertainty. Table 2-3 shows that the

TABLE 2-3

Comparison of Duration of Illness Data for Each Etiologic Agent

	Value Used for WBDO Reports with no Duration of Illness Entry (days)	WBDOSS Data Source	Non-WBDOSS Sources Used for WBDO Analysis	Percival et al. (2004)		Hunter (1997)		Pond (2005)		AMA Foodborne Illnesses Primer (AMA, 2004)	
				Approximate Range							
				min	max	min	max	min	max	min	max
AGI	4.2	AGI mean									
Norovirus	2	Norovirus mean		2	3	1	2	np[a]	np	0.5	4.5
SRSV (assumed to be norovirus)	2	Norovirus mean		np	np	np	np	np	np	np	np
Rotavirus	5.5		CDC fact sheet[b]	np	np	1	5	np	np	4	8
Hepatitis A	21		Ciocca (2000)	few weeks	2-3 months	weeks		several weeks	months	2 weeks	3 months
C. jejuni	4.4	*C. jejuni* mean		np	np	np	np	1 day	3 weeks	2	10
E. coli O157:H7 & other	5.3	*E. coli* mean		1 day	weeks	7	14	<5 days	5 days	3	10
E. coli O157:H7 *& Campylobacter*	4.8	Bacterial mean		np	np	np	np	np	np	np	np
P. shigelloides	4.8	Bacterial mean		np	np	np	np	np	np	np	np

TABLE 2-3 cont.

	Value Used for WBDO Reports with no Duration of Illness Entry (days)	WBDOSS Data Source	Non-WBDOSS Sources Used for WBDO Analysis	Percival et al. (2004)		Hunter (1997)		Pond (2005)		AMA Foodborne Illnesses Primer (AMA, 2004)	
				Approximate Range							
				min	max	min	max	min	max	min	max
Salmonella, non-typhoid spp.	6		CDC fact sheet[c]	2	5	couple of days	couple of weeks	np	np	4	7
S. enterica serovar Typhi	21		CDC fact sheet[d]	2 weeks	3 weeks	weeks	weeks	3 weeks	4 weeks	np	np
Shigella	3.8	*Shigella* mean		4	10	few days	week	4 days	7 days	4	7
V. cholerae	4.8	Bacterial mean		np	np	5[e]	7[e]	np	np	3	7
Yersinia	7.5	*Yersinia* mean		np[f,g]	np[f,g]	1 week	3 weeks	np	np	1 week	3 weeks
Cryptosporidium	8.8	*Crypto* median		1 week	2 weeks	2 days	26 days	2 weeks	3 weeks	weeks	months
Cyclospora	10		Herwaldt (2000)	5 days	15 weeks	1 week	8 weeks	np	np	weeks	months
En. histolytica	15		Stanley (2003)	weeks		np	np	np	np	several weeks	several months
Giardia	12.7	*Giardia* mean		1 week	3 weeks	10 days	12 weeks	3 days	several weeks	days	weeks

[a] np = not provided
[b] http://www.cdc.gov/ncidod/dvrd/revb/gastro/rotavirus.htm

[c] http://www.cdc.gov/ncidod/dbmd/diseaseinfo/salmonellosis_g.htm
[d] http://www.cdc.gov/ncidod/dbmd/diseaseinfo/typhoidfever_t.htm
[e] mild cases
[f] for immunocompetent persons
[g] Percival et al. cite additional ranges and central tendencies from several studies: primary health care patients who submitted fecal samples: mean 9 days, median 7 days, range 1-90 days (Palmer and Biffin, 1990); selected patients in two Australian cities: mean 22 days with range of 1-100 and mean 19 days with range 2-120 (Robertson et al., 2002); and experimental subjects without previous exposure: 6.5 days (Dupont et al., 1995); and experimental subjects with prior exposure: 3.1 days.

selected central tendency estimates are within the ranges reported by other authors. We note that the duration of illness estimate for the two *Vibrio cholerae* outbreaks was derived from the mean of median durations of illness of all bacterial WBDOs (rather than other literature). The illnesses that occurred during the two cholera WBDOs were relatively mild, whereas the typical literature values that are available describe severe cases associated with foreign travel (e.g., Eberhart-Phillips et al., 1996). We considered these inappropriate for the outbreaks reported in the WBDOSS. We note that our estimated midpoint is consistent with the low-end of Hunter (1997) and within the range reported by AMA (2007). No duration of illness was reported for the single *Cyclospora* WBDO reported in the surveillance system. We used a duration of illness of 10 days, as reported by Herwaldt (2000) as a median duration for several U.S. outbreaks; the median illness duration reported in this manuscript is consistent with the ranges reported in other literature summaries (Table 2-3). Other data sources were not available for estimating the *Plesiomonas shigelloides* outbreak; so the mean of median durations of all bacterial illnesses from the WBDO database was used for this agent.

The Milwaukee outbreak contributes a considerable portion of the total number of person-days ill to this WBDO burden analysis (see Chapter 3). While the large estimated case number (403,000) is one aspect of the person-days ill burden, the magnitude of this component is also influenced by the duration of illness value recorded in the WBDOSS (i.e., 9 days). Although Mac Kenzie et al. (1994) report a single duration value of 9 days in the abstract of their published article, their outbreak investigation involved three different surveys of persons in the Milwaukee area during the outbreak. Each group was characterized by different mean and median illness durations: (1) persons with laboratory confirmed cryptosporidiosis (median, 8.8 days), (2) persons with clinical symptoms consistent with cryptosporidiosis) (median, 3 days), and (3) a household survey of persons with watery diarrhea (median, 3 days) (Table 2-4). The reported duration of illness among these populations ranged from 1 to 55 days. Of the 285 laboratory-confirmed cases, 46% were hospitalized and 48% were immuno-compromised, and these cases may have been among the most severe. We examine the potential impact of the duration of illness selection (3 vs. 9 days) on the person-days ill component of the Milwaukee outbreak in an uncertainty analysis in Chapter 6.

2.4. PHYSICIAN VISITS

The number of physician visits likely is underreported in the WBDOSS because this information is not requested on CDC 52.12. Only 29 WBDO reports included

TABLE 2-4

Duration of Illness, Milwaukee *Cryptosporidium* Outbreak (Mac Kenzie et al., 1994)

Population Surveyed	Duration (Days)			Survey Information
	Median	Mean	Range	
Laboratory-Confirmed Cases	9	12	1-55	n=285 lab-confirmed cases
Clinical Infection	3	4.5	1-38	n=201 respondents with watery diarrhea (482 total respondents)
Household Survey	3	-	1-45	n=436 interviewees reporting watery diarrhea (out of 1663 total household members)

supplementary physician visit data, and only 5.2% of all cases reported for those 29 WBDOs were associated with such visits. When available, we used the physician visit rate reported in the WBDOSS for the same etiologic agent to estimate unreported rates (Table 2-5). For example, for the 118 WBDOs of giardiasis for which no physician visits were reported, we estimated a physician visit ratio of 307.4 physician visits per 1000 reported cases based on the physician visit reports provided with 8 of the 126 total giardiasis WBDOs. If there were no physician visit reports for a particular agent, we pooled information from the relevant class of agent as an estimate. For example, the physician visit counts for the one *Cryptosporidium* and the eight *Giardia* outbreak reports that included that information were pooled and the sum was divided by the total cases reported for those nine outbreaks to compute a physician visit ratio estimate of 50.6/1000 to apply to the other protozoan outbreaks (*Cyclospora* and *En. histolytica*). As shown in Figure 2-1 for the method used to estimate missing illness duration data, the use of such surrogate information to estimate a rate of physician visits for an agent is associated with additional uncertainty.

Information for physician visit rates was extremely limited for the bacterial and viral agents. For bacterial outbreaks, there were data for two *C. jejuni* WBDOs (51 physician visits out of 880 reported cases) and for one *S. enterica* serovar Typhi outbreak (for which there were only two cases reported, and both cases involved a physician visit). Because the reported typhoid outbreak was so small and because typhoid tends to be a markedly more severe illness than the other bacterial illnesses reported to the WBDOSS, we elected to use only the physician visit rate for *C. jejuni* as the representative bacterial WBDO physician visit rate (58/1000). For viral outbreaks, the physician visit rate derived from the one rotavirus WBDO serves as the estimated rate for norovirus and SRSV. Although physician visits were reported for one Hepatitis A WBDO, it is not included in this group.[2]

We estimated physician visits only for those WBDOs in which the number of hospitalizations constituted fewer than 75% of the reported cases of illness (n=629). If the number of hospitalizations was greater than 75%, we assumed the severity of the outbreak illnesses resulted in few cases treated on an outpatient basis.

Because the physician visit estimates are based upon very few reported values (recall that this information is not requested on CDC 52.12), and we were unable to

[2] Unlike the other viral agents in the WBDO database (i.e., rotavirus, norovirus, and SRSV), Hepatitis A causes non-gastrointestinal illness. Hepatitis tends to be considerably more severe than the gastrointestinal (GI) illnesses caused by the other viruses, so we have elected to present Hepatitis A WBDO data separately from other viral WBDOs and restrict the physician visit estimate for non-reported norovirus to data from a GI viral WBDO.

TABLE 2-5

Physician Visits (PV) by Etiologic Agent, Reported WBDOs, 1971 to 2000

Etiologic Agent	All WBDOSS Outbreaks		WBDOs that Reported Physician Visits				Estimated (PV per 1000 Cases)	Source of PV Value (all from WBDOSS data)
	Out-breaks	Cases	Out-breaks	Cases	PVs Reported in WBDOSS	PV per 1000 Cases		
AGI	365	83,493	14	7,664	810	105.7	105.7	AGI
Viruses								
Norovirus	26	13,100	-	-	-	-	82.9	Rotavirus
SRSV (assumed to be norovirus)	1	70	-	-	-	-	82.9	Rotavirus
Rotavirus	1	1,761	1	1,761	146	82.9	82.9	Rotavirus
Hepatitis A	28	827	2	103	100	970.9	970.9	Hepatitis A
Bacteria								
C. jejuni	19	5,604	2	880	51	58.0	58.0	*C. jejuni*
E. coli O157:H7 & other	12	1,529	-	-	-	-	58.0	*C. jejuni*[a]
E. coli O157:H7 *& Campylobacter*	1	781	-	-	-	-	58.0	*C. jejuni*
P. shigelloides	1	60	-	-	-	-	58.0	*C. jejuni*

TABLE 2-5 cont.

Etiologic Agent	All WBDOSS Outbreaks		WBDOs that Reported Physician Visits				Estimated (PV per 1000 Cases)	Source of PV Value (all from WBDOSS data)
	Out-breaks	Cases	Out-breaks	Cases	PVs Reported in WBDOSS	PV per 1000 Cases		
Salmonella, non-typhoid spp.	15	3,203	-				58.0	*C. jejuni*[b]
S. enterica serovar Typhi	5	282	1	2	2	1000	1000	*S. enterica* serovar Typhi
Shigella	44	9,196	-	-	-	-	58.0	*C. jejuni*
V. cholerae	2	28	-	-	-	-	58.0	*C. jejuni*
Yersinia	2	103	-	-	-	-	58.0	*C. jejuni*
Protozoa								
Cryptosporidium	15	421,473	1	403,000	20,280	50.3	50.3	*Cryptosporidium*
Cyclospora	1	21	-	-	-	-	50.6	All protozoa
En. histolytica	1	4	-	-	-	-	50.6	All protozoa
Giardia	126	28,427	8	462	142	307.4	307.4	*Giardia*
Total	665	569,962	29	413,872	21,531			

[a] Outbreaks caused by enterohemorrhagic strains of *E. coli* can cause severe illnesses; it is unclear whether the waterborne outbreaks attributed to *E. coli* examined long-term sequelae.
[b] Between 1996-1999, Voetsch et al. (2004) report a physician visit rate of 12% for culture-confirmed non-typhoid *Salmonella* infections, which is roughly double our estimate.

locate peer-reviewed literature for alternative estimates, this component of the burden estimate is highly uncertain. The sensitivity of the burden estimate to the uncertainty of the physician visit data is examined in Chapter 6.

2.5. EMERGENCY ROOM VISITS

As with physician visits, the reporting of emergency room visits during a WBDO is not requested on CDC 52.12. Supplementary information on emergency room visits was provided with a few reports (15) and in these outbreaks only 6% of cases were associated with emergency room visits. Since emergency room visits were infrequently reported, most estimates were based on the pathogen group. For example, emergency room visits were reported for only one of the 126 giardiasis outbreaks and none of the other protozoan outbreaks; the rate for that one outbreak (29.1 per 1000 reported cases) is used for all protozoan WBDOs. The values used to estimate the burden are shown in Table 2-6. Similar to unreported physician visits, unreported emergency room visits were estimated only for WBDOs in which less than 75% of cases were hospitalized.

Since the number of WBDOs resulting in reported emergency room visits was small, there is considerable uncertainty in this outbreak severity measure category. To our knowledge, there are no other sources in the peer-reviewed literature that can be used for alternative estimates. As shown for illness duration in Figure 2-1, the use of such surrogate information is associated with additional uncertainty. The sensitivity of the burden estimates to the uncertainty of the data on emergency room visits is examined in Chapter 6.

2.6. HOSPITALIZATIONS

CDC 52.12 requests the number of hospitalizations occurring during an outbreak, and 659 of the WBDO reports (99%) included this information. An entry of “zero” was provided in 496 of the reports; one or more hospitalizations were recorded in each of the remaining 163 reports, for a total of 5915 hospitalizations. For the additional six outbreak reports, which provided no hospitalization information, we assumed there were no hospitalized cases. Because this information was reported for almost all of the WBDOs, the hospitalization rates for WBDO illnesses were determined by dividing the number of reported hospitalizations for an etiologic agent by the total number of cases reported for that agent (Table 2-7). Because the reporting frequency was 99%, no additional hospitalization rates were estimated for the 1% of the remaining outbreaks.

TABLE 2-6

Emergency Room (ER) Visits by Etiologic Agent, WBDOs, 1971 to 2000

Etiologic Agent	All WBDOSS Outbreaks		WBDOs that Reported Emergency Room Visits				Estimated (ER per 1000 Cases)	Source (all from WBDOSS Data)
	Outbreaks	Cases	Outbreaks	Cases	ER Visits in WBDOSS	ER Visits/ 1000 Cases		
AGI	365	83,493	9	7,839	885	112.9	112.9	AGI
Viruses								
Norovirus	26	13,100	1	1,500	5	3.3	3.3	Norovirus
SRSV (assumed to be norovirus)	1	70	0	0	0	0	3.3	Norovirus
Rotavirus	1	1,761	0	0	0	0	3.3	Norovirus
Hepatitis A	28	827	1	22	2	90.9	90.9	Hepatitis A
Bacteria								
C. jejuni	19	5,604	2	3,871	11	2.8	2.8	*C. jejuni*
E. coli O157:H7 & other	12	1,529	0	0	0	0	4.8	All bacteria[a]
E. coli O157:H7 *& Campylobacter*	1	781	0	0	0	0	4.8	All bacteria
P. shigelloides	1	60	0	0	0	0	4.8	All bacteria
Salmonella, non-typhoid spp.	15	3,203	0	0	0	0	4.8	All bacteria

TABLE 2-6 cont.

Etiologic Agent	All WBDOSS Outbreaks		WBDOs that Reported Emergency Room Visits				Estimated (ER per 1000 Cases)	Source (all from WBDOSS Data)
	Outbreaks	Cases	Outbreaks	Cases	ER Visits in WBDOSS	ER Visits/ 1000 Cases		
S. enterica serovar Typhi	5	282	0	0	0	0	4.8	All bacteria
Shigella	44	9,196	1	83	8	96.4	96.4	Shigella
V. cholerae	2	28	0	0	0	0	4.8	All bacteria
Yersinia	2	103	0	0	0	0	4.8	All bacteria
Protozoa								
Cryptosporidium	15	421,473	0	0	0	0[b]	29.1	*Giardia*
Cyclospora	1	21	0	0	0	0	29.1	*Giardia*
En. histolytica	1	4	0	0	0	0	29.1	*Giardia*
Giardia	126	28,427	1	3,500	102	29.1	29.1	*Giardia*
Total	665	569,962	15	16,815	1,013			

[a] A total of 19 ER visits were reported for the three outbreaks attributed to bacteria that included supplemental ER information (11 for *C. jejuni* + 8 for *Shigella*). The total case number of these three outbreaks was 3954. The "all bacteria" ER hospitalization rate was computed as: (3,954 / 19) * 1000.

[b] Based on medical chart data, Corso et al. (2003) in their Table 1 reported that 5% of the moderate cryptosporidiosis cases attributed to the Milwaukee outbreak visited the emergency room. Table 3 of their manuscript reported that there were 44,000 moderate cryptosporidiosis cases attributed to the Milwaukee outbreak. Assuming the size of the Milwaukee outbreak to be 403,000 cases yields an emergency room visit rate of 5.5 per 1000 cases of cryptosporidiosis.

TABLE 2-7

Hospitalizations, Reported WBDOs, 1971 to 2000

Etiologic Agent	All WBDOs Outbreaks		WBDOs with Reported Hospitalizations			Hospitalization Rate (Hospitalized cases per 1000 total cases)
	Outbreaks	Cases	Outbreaks	Cases	Hospitalizations	
AGI	365	83,493	61	41,710	378	4.5
Viruses						
Norovirus	26	13,100	4	1,154	10	0.8
SRSV (assumed to be norovirus)	1	70	0	–	–	0
Rotavirus	1	1,761	0	–	–	0
Hepatitis A	28	827	12	348	82	99.1
Bacteria						
C. jejuni	19	5,604	8	5,178	87	15.5
E. coli O157:H7 & other	12	1,529	9	520	122	79.8
E. coli O157:H7 *& Campylobacter*	1	781	1	781	71	90.9
P. shigelloides	1	60	1	60	3	50
Salmonella, non-typhoid spp.	15	3,203	8	1,910	82	25.6
S. enterica serovar Typhi	5	282	4	277	238	844
Shigella	44	9,196	22	5,813	301	32.7

TABLE 2-7 cont.

Etiologic Agent	All WBDOs Outbreaks		WBDOs with Reported Hospitalizations			Hospitalization Rate (Hospitalized cases per 1000 total cases)
	Outbreaks	Cases	Outbreaks	Cases	Hospitalizations	
V. cholerae	2	28	1	11	4	142.9
Yersinia	2	103	2	103	20	194.2
Protozoa						
Cryptosporidium	15	421,473	7	407,521	4,448	10.6
Cyclospora	1	21	0	–	–	0
En. histolytica	1	4	1	4	1	250.0
Giardia	126	28,427	22	13,423	68	2.4
Total	665	569,962	163	478,813	5,915	

Although we did not employ any estimation procedures to supplement the hospitalization data from the WBDOSS, in Section 2.8 we provide a comparison of the WBDO rates of hospitalization to those estimated by Mead et al. (1999). The Mead et al. study was designed to evaluate the impact of foodborne illnesses on the disease burden in the U.S. due to infectious agents that primarily cause gastrointestinal illnesses.

2.7. MORTALITY

CDC 52.12 requests the number of fatalities associated with a WBDO, and all WBDO reports included an entry for deaths. This entry was zero for 559 WBDOs but six of the outbreaks reported one or more deaths (Table 2-8). Because this information was reported for all of the WBDOs, the fatality-case ratios for WBDO illnesses were determined by dividing the number of reported deaths for an etiologic agent by the total number of cases from all outbreaks reported for that agent and normalizing these ratios to 100,000 cases.

It is unclear to what extent local investigators conducted specific analyses of mortality or searched death certificates for possible WBDO-related deaths. For the Milwaukee outbreak, Hoxie et al. (1997) assessed cryptosporidiosis-associated mortality incidence before, during, and after the 1993 WBDO period. They reported that an excess of 50 deaths occurred as a result of the WBDO; the underlying cause of most of these deaths was acquired immunodeficiency syndrome (AIDS) with cryptosporidiosis listed as a contributing cause. However, the investigators who reported deaths for the other five WBDOs did not specify the source of information about the deaths nor did they note whether the infectious disease of the outbreak was the underlying or a contributing cause of death. Issues associated with the possible under- or over-reporting of mortality are discussed in Section 2.9.

2.8. COMPARISON OF WBDOSS AND MEAD ET AL. (1999) HOSPITALIZATION RATES

To examine possible under- or over-reporting of hospitalizations in the WBDOSS, we compared the pathogen-specific and AGI hospitalization rates for WBDOs with pathogen-specific and AGI hospitalization rates reported in Mead et al. (1999). The objective of the Mead et al. report was to estimate the burden of foodborne infectious disease in the U.S.; the paper, however, also reports estimates of total cases, hospitalizations, and deaths associated with microbial pathogens that, though potentially foodborne, can also be transmitted by water or person-to-person contact.

TABLE 2-8

Mortality Reported in the WBDOSS, 1971-2000, by Etiology

Etiologic Agent	Reported Outbreaks		Outbreaks with One or More Reported Deaths			Case Fatality Ratio per 100,000 cases (Reported Deaths divided by Reported Cases x 100,000)
	Outbreaks	Cases	Outbreaks	Cases	Reported Deaths	
AGI	365	83,493	1	38	1	1.2
Viruses						
Norovirus	26	13,100	0	–	–	–
SRSV (assumed to be norovirus)	1	70	0	–	–	–
Rotavirus	1	1,761	0	–	–	–
Hepatitis A	28	827	0	–	–	–
Bacteria						
C. jejuni	19	5,604	0	–	–	–
E. coli O157:H7* *E. coli* O6:H16*	11 1	529 1,000	1 0	243 –	4 –	756
E. coli O157:H7 & *Campylobacter*	1	781	1	781	2	256.1
P. shigelloides	1	60	0	–	–	–
Salmonella, non-typhoid spp.	15	3,203	1	625	7	218.5
S. enterica serovar Typhi	5	282	0	–	–	–

TABLE 2-8 cont.

Etiologic Agent	Reported Outbreaks		Outbreaks with One or More Reported Deaths			Case Fatality Ratio per 100,000 cases (Reported Deaths divided by Reported Cases x 100,000)
	Outbreaks	Cases	Outbreaks	Cases	Reported Deaths	
Shigella	44	9,196	1	94	2	21.7
V. cholerae	2	28	0	–	–	–
Yersinia	2	103	0	–	–	–
Protozoa						
Cryptosporidium	15	421,473	1	403,000	50	11.9
Cyclospora	1	21	0	–	–	–
En. histolytica	1	4	0	–	–	–
Giardia	126	28,427	0	–	–	–
Total	665	569,962	6	404,781	66	

* All of the *E. coli* deaths were specifically attributed to strain O157:H7.

Mead and colleagues used information from a number of surveillance sources including the *Foodborne Diseases Active Surveillance Network* (FoodNet) (CDC, 1999a), the *National Notifiable Diseases Surveillance System* (CDC, 1998a), the *Public Health Laboratory Information System* (Bean et al., 1992), the *Gulf Coast States Vibrio Surveillance System* (Levine and Griffin, 1993), the *Foodborne Disease Outbreak Surveillance System* (Bean et al., 1990), the *National Hospital Ambulatory Medical Care Survey* (Woodwell, 1997), the *National Hospital Discharge Survey* (Graves and Gillium, 1997), the *National Vital Statistics System* (McCaig, 1997; McCaig and McLemore, 1994; McCaig and Stussman, 1997), CDC reports, and selected published studies. The Mead et al. report included pathogen-specific hospitalization rates for cases that were culture-confirmed or actually reported (to FoodNet, CDC or published outbreak reports), and estimated the number of hospitalizations for estimated total case numbers (Table 2-9). We also provide WBDOSS hospitalization rates in Table 2-9 for comparison.

The values for the confirmed/reported cases from Mead et al. (Table 2-9, fourth column) reflect higher hospitalization rates while the rates for estimated total case numbers (Table 2-9, fifth column) are typically lower. Consider that patients hospitalized for gastrointestinal illness would be tested routinely for pathogens; this would likely result in a high hospitalization rate among the cases confirmed by hospital laboratories. In contrast, the estimated-cases category would include many mild and non-medically-attended cases—so a lower hospitalization rate would be expected. The WBDO hospitalization rates generally fall between the confirmed/reported and estimated rates of Mead et al., or near the estimated rate. The exceptions were WBDOs of *Cyclospora*, *V. cholerae*, *S. enterica* serovar Typhi, and rotavirus. For *Cyclospora*, the case number sample size (n=21) in the WBDO database was too small to expect representative information regarding this agent. The *V. cholerae* hospitalization rate from Mead et al. was based almost exclusively on foreign-acquired infection and may not be appropriate for the two WBDOs in the U.S. that were characterized by relatively mild illness for this pathogen.[3] The hospitalization rate for WBDOs of *S. enterica* serovar Typhi is somewhat higher than the Mead et al. rates, but all the presented rates (844, 750 and 750 hospitalizations per 1000 reported cases) are markedly higher than that for any other pathogen and the relative difference between them is small. There were no reported hospitalizations associated with the single

[3] For example, Eberhart-Phillips et al. (1996) reported that a total of 75 passengers on an airliner traveling from a foreign country to the U.S. contracted cholera. The hospitalization rate for this 1992 foodborne cholera outbreak was 133.3/1000.

TABLE 2-9

Hospitalization Rate (Hospitalized cases per 1,000 cases)

Etiologic Agent	Total WBDO Cases	WBDOSS (Based on reported hospitalizations relative to total WBDO Cases)	Mead et al. (1999); Culture-Confirmed/Reported (Based on cases reported to CDC)[a]	Mead et al. (1999); Estimated (Based on estimated total cases)[b]
AGI	83,493	4.5	-	4.5
Viruses				
Norovirus	13,100	0.8	-	2.1
SRSV (assumed to be norovirus)	70	0	-	-
Rotavirus	1,761	0	-	12.8
Hepatitis A	827	99.1	130	130
Bacteria				
C. jejuni	5,604	15.5	102	5.4
E. coli O157:H7 & other	1,529	79.8	295	29.5
E. coli O157:H7 *& Campylobacter*	781	90.9	-	-
P. shigelloides	60	50	-	-
Salmonella, non-typhoid spp.	3,203	25.6	221	11.6
S. enterica serovar Typhi	282	844	750	750
Shigella	9,196	32.7	139	13.9
V. cholerae	28	143	340	333[c]
Yersinia	103	194	242	12.7
Protozoa				
Cryptosporidium	421,473	10.6	150	6.6
Cyclospora	21	0	20	1.0
En. histolytica	4	250	-	-
Giardia	28,427	2.4	-	2.5[a]

[a] Estimated hospitalization rates reported in Table 2 of Mead et al. (1999).
[b] The estimated rate for hospitalizations amongst total estimated cases was determined by dividing the total estimated hospitalizations by the total estimated illnesses for each pathogen. These case and hospitalization numbers for specific pathogens are provided by Mead et al. (1999) in their Table 3, and for AGI in their Figure 1.
[c] 96% of cases reported to CDC were acquired abroad.

reported WBDO of rotavirus that occurred primarily among adult tourists (n=1761) in a resort area. The hospitalization rate estimated by Mead et al. for rotavirus (12.8/1000) probably reflects the hospitalization rate for young children who typically experience much more severe illness from rotavirus infections than do adults.

2.9. COMPARISON OF FATALITY PER CASE ESTIMATIONS

Although all the WBDO reports included entries for deaths due to the outbreak, under- or over-reporting of the number of deaths is possible. Deaths that occur as a result of a WBDO-acquired illness may not get attributed to that cause of death on the WBDOSS report or on the patient's death certificate. Unless an outbreak investigation includes an evaluation of death certificates or a mortality study that considers deaths before, during, and after the WBDO, reported deaths might not represent the actual mortality attributable to the outbreak. Even though a death may occur during the outbreak period or shortly thereafter, an attending physician may not certify that the WBDO pathogen was a contributing or underlying cause of death, or an outbreak investigator may not conclude that a death is WBDO-related, even if the illness or infectious agent etiology is listed on the death certificate. For example, no deaths were indicated on the CDC 52.12 filed to report a cryptosporidiosis outbreak that occurred in Clark County, Nevada over the first 3 months of 1994. However, there were at least 20 cryptosporidiosis-associated deaths among HIV-positive persons that occurred in Clark County by the end of June that year (Goldstein et al., 1996). Although these deaths may have been attributable to the waterborne outbreak, they are not recorded in the WBDOSS.

To investigate possible under- or over-reporting of mortality resulting from WBDOs, we considered four other estimates of mortality due to infectious diseases that can be food or waterborne (Table 2-10). Three of the other compilations address the burden of foodborne illnesses: Mead et al. (1999), Todd (1989) and the Council for Agricultural Science and Technology (CAST, 1994) and the fourth, Bennett et al. (1987), addresses the burden of all infectious diseases in the U.S.

Based on data listed in the hospitalization-rate discussion above, Mead et al. reported pathogen-specific fatality-case ratios for confirmed/reported cases and estimated the number of deaths occurring amongst the estimated total cases. Todd's fatality-case ratios were based upon the Bennett et al. (1987) report and other sources including CDC annual summary data, CDC correspondence, and published reports. The CAST task force compiled case number and mortality data reported for foodborne outbreaks that occurred in the period from 1983 through 1987. The fatality-case ratios

TABLE 2-10

Case Fatalities per 100,000 Cases According to Waterborne Disease Outbreak Surveillance System and Other Sources

Etiologic Agent	WBDOSS (1971 to 2000)	Foodborne Outbreaks Reported to CDC: 1983-1987; CAST[a] (1994)	Mead et al. (1999)		Bennett et al. (1987) from *Closing the Gap*	Todd (1989) for Foodborne Disease[d]	
			Based on Culture-Confirmed or Reported to FoodNet/CDC	Based on Estimated Cases[b]	Based on "Est. True Annual Incidence" CDC Survey Data[c]	Based on Reported Cases	Based on Estimated Cases
AGI	1.2	-	-	2[e]	-	40	0.4
Viruses							
Norovirus	0	0	-	1[f]	0.1	0.1	0
SRSV (assumed to be norovirus)	-	-	-	-	-	-	-
Rotavirus	0	0	-	0[g]	10	-	-
Hepatitis A	0	94	300[h]	100	300	300	3
Bacteria							
C. jejuni	0	138	100[i]	5.1	100	50	0.5
E. coli O157:H7 (excluding the *E. coli* O157:H7 deaths from the mixed outbreak)	756	625	830[j]	83	200	2,000	20
P. shigelloides	0	-	-	-	-	-	-
Salmonella, non-typhoid spp.	219	125	780[k]	41	100	100	1.1
S. enterica serovar Typhi	0	-	400[l]	364	6,000[m]	-	60
Shigella	21.7	30	160[k]	15.6	200	125	1.25
V. cholerae	0	0	600[n]	0	1,000[m]	1,000	10

TABLE 2-10 cont.

Etiologic Agent	WBDOSS (1971 to 2000)	Foodborne Outbreaks Reported to CDC: 1983-1987; CAST[a] (1994)	Mead et al. (1999)		Bennett et al. (1987) from *Closing the Gap*	Todd (1989) for Foodborne Disease[d]	
			Based on Culture-Confirmed or Reported to FoodNet/CDC	Based on Estimated Cases[b]	Based on "Est. True Annual Incidence" CDC Survey Data[c]	Based on Reported Cases	Based on Estimated Cases
Yersinia	0	-	50[o]	3.1	50	25	0.25
Protozoa							
Cryptosporidium	11.9	-	500[p]	22	50,000[m]	-	-
Cyclospora	0	-	50[q]	0	-	-	-
En. histolytica	0	-	-	-	300	-	-
Giardia	0	0	-	0.5[r]	0.1	1	0

[a] Council for Agricultural Science and Technology (CAST)
[b] Table 3, Mead et al. (1999), Estimated total deaths/Estimated total cases.
[c] From chapter entitled "Infectious and Parasitic Diseases" in *Closing the Gap: the Burden of Unnecessary Disease,* a 1987 Carter Center Report. Estimates acquired from CDC experts and based on 1985 case incidence and infection-attributable death records.
[d] Fatality:case ratios (as %) presented in Table 2, Todd (1989). Note: Fatality:case ratios for estimated cases assumed to be 100X lower than for reported cases.
[e] 5,000 deaths/173,000,000 cases AGI (Figure from Mead et al., 1999).
[f] Assumed to account for 11% of 2,800 fatal cases of viral AGI each year. Mead appendix reference to Mounts et al. (1999).
[g] "Very low." Mead appendix reference to Kilgore et al. (1995).
[h] Based on hepatitis surveillance. Mead appendix references to Hepatitis Surveillance Report no. 56 (1996) and Hoofnagle et al. (1995).
[i] Culture-confirmed cases reported to FoodNet, 1996/97. Mead appendix reference to FoodNet (CDC, 1998b,c).
[j] Mortality associated with sporadic cases reported to FoodNet, 1996/97. Mead appendix reference to FoodNet (CDC, 1998b,c).
[k] Average case-fatality rate reported to FoodNet, 1996/97. Mead appendix reference to FoodNet (CDC, 1998b,c).
[l] Based on outcomes of 2254 cultured-confirmed cases. Mead appendix reference to Mermin et al. (1998).
[m] Based on small numbers: Typhoid 36 deaths/600cases; Cholera 3 deaths/25 cases; Crypto 25 deaths/50 cases.
[n] Based on cases reported to CDC, 1992-94. Mead appendix reference to Mahon et al (1996).
[o] Case-fatality rate assumed to be low (0.5%) based on 1996 FoodNet surveillance. Mead appendix reference to FoodNet (CDC, 1998b).
[p] Average case-fatality rate among cases reported to FoodNet, 1997/98. Mead appendix reference to FoodNet (CDC, 1998c, 1999a).
[q] Case-fatality rate assumed low (0.5%). Mead appendix reference to Herwaldt and Ackers (1997) and Herwaldt et al. (1999).
[r] Case-fatality rate assumed to be "exceedingly low" (Mead et al., 1999 [appendix]).

reported by Bennett et al. were obtained from survey data collected from experts in the various divisions of the CDC regarding infectious disease incidence in 1985.

Note that the Mead et al., CAST and Todd fatality-case ratios for "reported" cases in Table 2-10 are consistently greater than those for "estimated" cases. This phenomenon occurs because estimated case numbers include unreported cases and, frequently, unreported cases include the milder episodes of illness, many of which do not require medical attention. Far fewer fatalities per incident number of cases can be expected when large numbers of mild cases are included in the total. Furthermore, culture-confirmation of a case would much more likely be sought for patients who present to their physicians with severe symptoms; consequently, a higher fatality-case ratio can be expected for culture-confirmed cases. To estimate the number of deaths occurring among the estimated cases, Mead et al. calculated the number of reported pathogen-specific deaths available from FoodNet, reported outbreaks, and other published sources (see footnotes in Table 2-10) and assumed that twice that many deaths might have occurred among the estimated cases (two times the number of reported deaths/estimated number of cases). For those viral and protozoan agents with no reported deaths, the fatality-case ratio was estimated from literature review. Todd assumed that the fatality-case ratio for estimated case incidence was 100-fold less than that computed for reported cases. The approach for determining fatality-case ratios in Bennett et al. is unclear and appears to represent estimated cases for some etiologic agents and reported cases for others. The fatality-case ratios for some of the etiologic agents in the Bennett et al. report appear to be based on very low case numbers, such as those for *Cryptosporidium*, *V. cholerae,* and *S. enterica* serovar Typhi*.* The reporting of very few cases of cryptosporidiosis by Bennett et al. and the extremely high fatality-case ratio associated with them were likely affected by the fact that these data are from 1985, which was very early in the course of the U.S. HIV-AIDS epidemic. Prior to the AIDS epidemic, cryptosporidiosis was rarely recognized or reported. The reported cases of cryptosporidiosis that occurred in AIDS patients in 1985 would likely have been severe and often fatal.

Fatality-case ratios for the reported WBDOs were zero except for *E. coli* O157:H7 (and one WBDO attributed to *E. coli* O157:H7 and *Campylobacter* but in which the deaths were specifically associated with *E. coli* O157:H7), non-typhoid *Salmonella* spp*., Shigella, Cryptosporidium* and AGI. Fatality-case ratios of zero can be expected among many of the reported WBDO etiologies, in part, because so few cases of any of the types of infectious diseases included in the WBDOSS are reported, and, in general, overall fatality-case ratios for these diseases are low when the total case incidence from

all causes is estimated. For example, using the fatality-case ratio developed by the most recent literature source considered here—Mead et al. (1999)—one death per 20,000 estimated cases of campylobacteriosis could be expected (fatality-case ratio, 0.00005).[4] Since the WBDOSS includes only 5604 cases attributable to *Campylobacter* spp., it is not surprising that there was no report of deaths attributed to *Campylobacter* spp.

The cases of illness reported to the WBDOSS included not only symptom- and culture-confirmed cases, but also included estimated case numbers for some outbreaks. It is reasonable to expect that for some etiological agents, the fatality-case ratios would be closer to the reported/confirmed case ratios provided by CAST, Mead et al., and Todd, while for others they would be closer to the estimated case ratios, depending on the proportion of estimated cases in the WBDO case total for a particular agent. Except for *Cryptosporidium*, all WBDO agent categories that included a non-zero fatality-case ratio (AGI, *E. coli* O157:H7, non-typhoid *Salmonella* spp., and *Shigella*) were between the confirmed/reported and estimated values of the literature based compilations. The WBDOSS fatality-case ratio for *Cryptosporidium* of 11.9 deaths/100,000 cases is less than the lowest literature-source value of 22 deaths/100,000 cases proposed by Mead et al. for estimated cases (Table 3, Mead et al., 1999). We considered the range for the number of deaths that might have occurred during the 30-year WBDO reporting period if the fatality-case ratios acquired from the aforementioned literature sources were used for estimation of the expected (rather than WBDOSS-reported) number of deaths. We applied the lowest and the highest values offered by the four sources (except for the Bennett *Cryptosporidium*[5] and *S. enterica* serovar Typhi[6] values) to the reported case numbers in the WBDO database to estimate the lowest and highest number of deaths that could plausibly be expected (Table 2-11). All of the lowest values for predicted numbers of deaths from WBDOs are based on fatality-case ratios developed for

[4] Mead et al. (1999) multiplied the number of reported deaths attributed to a specific pathogen by two (this factor was assumed to account for unreported deaths caused by the specific pathogen). They divided this product by the estimated number of cases to yield an estimated fatality-case ratio.

[5] Bennett et al. relies heavily on the subjective information they compiled. They used published statistics and estimated current and future waterborne infections based on a survey of experts. It appears that the Bennett et al. 50% fatality ratio is unrealistically large having been based on only the 50 cases that were estimated to be the "current incidence" in 1987 as determined by CDC experts from data collected in 1985. Furthermore, these may have been particularly severe considering that effective antiretroviral therapy for AIDS patients was not generally available at that time.

[6] The Bennett et al., fatality-case ratio for typhoid was based on the expectation of 36 deaths among 600 cases (6% of cases). This appears to be an exceptionally high value considering that Mermin et al. (1998), of the Foodborne and Diarrheal Diseases Branch of the CDC examined 2445 reports of culture-confirmed typhoid received by the CDC between 1985 and 1994 and found only 10 deaths reported from these cases (0.4%).

TABLE 2-11

Comparison of Number of Deaths Reported in WBDOs with Expected Number of Deaths Using Literature-Based Fatality-Case Ratios
(Rounded to nearest whole number; if values are <0.5 but >0, the entry is "<1")

	WBDO Reported Deaths	Low Estimate from Literature Sources	High Estimate from Literature Sources
AGI	1	<1[a]	33[b]
Viruses			
Norovirus	0	<1[b]	<1[c]
SRSV (assumed to be norovirus)	0	–	–
Rotavirus	0	<1[c]	<1[d]
Hepatitis A	0	<1[a]	2[e]
Bacteria			
C. jejuni	0	<1[a]	8[f]
E. coli O157:H7 and mixed *E. coli* O157:H7[g] *& C. jejuni*	6	<1[a]	46[b]
P. shigelloides	0	–	–
Salmonella, non-typhoid spp.	7	<1[a]	25[e]
S. enterica serovar Typhi	0	<1[a]	1[e]
Shigella	2	<1[a]	18[d]
V. cholerae	0	0[c]	<1[d]
Yersinia	0	0[a]	<1[e]
Protozoa			
Cryptosporidium	50	93[c]	2,107[e]
Cyclospora	0	0[c]	<1[e]
En. histolytica	0	–	<1[d]
Giardia	0	0[a]	<1[b]
Totals	66	94	2,243

[a] Based on Todd, fatality-case ratio for estimated case numbers.
[b] Based on Todd, fatality-case ratio for confirmed/reported case numbers.
[c] Based on Mead et al., fatality-case ratio for estimated case numbers.
[d] Based on Bennett et al., fatality-case ratios.
[e] Based on Mead et al., fatality-case ratio for confirmed/reported case numbers. See Footnotes 4 and 5 in text regarding Bennett et al.'s higher estimates for *S. enterica* serovar Typhi and *Cryptosporidium.*
[f] Based on CAST, fatality-case ratios
[g] Deaths and majority of infections in this outbreak due to *E. coli* O157:H7

estimated case totals. Many (9 of 15) of the lowest values are based on the fatality-case ratios provided by Todd for estimated cases (who assumed that the fatality-case ratio for estimated cases is 1/100 of that computed for reported/confirmed cases). All the highest predicted death numbers were calculated from fatality-case ratios that were based on reported/confirmed cases, and these are all greater than the reported WBDO number of deaths.

For three of the pathogen classifications, AGI, *E. coli* O157:H7, and *Cryptosporidium,* the high estimates were markedly greater than the reported WBDO deaths. Todd (1989) selected a 40/100,000 fatality-case ratio for 6309 reported cases of AGI and cites CDC annual summaries of foodborne disease surveillance for 1978, 1979, 1980, 1981 and 1982 as his source. Todd also provided the highest *E. coli* O157:H7 fatality-case ratio (2000 deaths/100,000 reported cases) for 30 reported cases as ascertained from the same CDC annual summaries cited above. The highest fatality-case ratio for cryptosporidiosis was provided by Bennett et al.; however, their 50,000 deaths/100,000 cases value indicates that there would have been over 200,000 deaths due to the Milwaukee outbreak. Because that estimation is implausibly excessive, we used the fatality-case ratio reported in Table 2 of Mead and collaborators for our upper-end estimate of *Cryptosporidium*-associated WBDO deaths in Table 2-11.

Over the 30-year surveillance period, 66 deaths were reported to the WBDOSS. If the lowest and highest literature-based fatality-case ratios are used, without modification, to predict the number of expected deaths among the cases in the WBDOSS, the range would be 94-2243 (Table 2-11). Obviously, these values are driven by the 403,000 cryptosporidiosis case from the Milwaukee outbreak. Because the Milwaukee case number was estimated (only 285 cases were culture-confirmed) we contend that the Mead et al. fatality-case ratio based on estimated cases (22/100,000) is the more appropriate choice for establishing a plausible range for deaths due to the WBDOs. This reduces the literature-based estimate for the *Cryptosporidium*-associated death toll to 93, and the range for predicted deaths becomes 94-228 (Table 2-12). And finally, because the *Cryptosporidium*-associated deaths attributed to the Milwaukee outbreak were extensively investigated by Hoxie et al. (1997), we suggest no further modification of the plausible range for total deaths by limiting the *Cryptosporidium*-associated deaths to the 50 reported to the WBDOSS. This yields a range of 51 to 185 predicted deaths due to reported WBDOs over 30 years (which contains the WBDOSS reported value of 66): for further analysis of mortality see Section 6.2. Hoxie and colleagues also demonstrate that the total number of AIDS deaths, excluding cryptosporidiosis- associated AIDS deaths, was significantly greater than predicted

TABLE 2-12

Modifications of the Plausible Predicted Number of WBDO Deaths Estimated from Literature-Based Fatality-Case Ratios

	Low Estimate from Literature Sources	High Estimate from Literature Sources
Totals from Table 2-11	94	2,243
Using only Mead et al., fatality-case ratio for estimated case numbers for *Cryptosporidium* (because the 403,000 cases of cryptosporidiosis were estimated for Milwaukee) yielding an estimate of 93 WBDO *Cryptosporidium* deaths	94	228
Using only the 50 *Cryptosporidium* deaths attributed to the Milwaukee outbreak data in the WBDOSS	51	185

during the 6 months after the outbreak (19 more deaths than expected [95% Confidence Interval (CI)=12, 26]), and that non-cryptosporidiosis-associated AIDS deaths were lower than expected during the subsequent two 6-month intervals, suggesting that premature mortality among persons with AIDS could have been associated with the outbreak, and that cryptosporidiosis as a contributing cause of death may have been under-reported on their death certificates. Under this assumption, the 19 excess AIDS deaths that occurred within six months after the outbreak may have been cryptosporidiosis-associated. This would increase the range of predicted deaths due to reported WBDOs over 30 years to 51-204.

2.10. EPIDEMIOLOGIC BURDEN SEVERITY MEASURES

The summary epidemiologic severity measures used for our burden analysis are presented in Table 2-13. The number of cases, hospitalizations and deaths are used as reported. Person-days ill, physician visit and emergency room visit numbers were derived with the estimation methods described earlier in this chapter. Inaccurate reporting and paucity of data create uncertainty in the burden measures. The sensitivity of the burden estimate to uncertainty in the various burden components is examined in Chapter 6.

TABLE 2-13

Epidemiologic Burden Measures Used in the Analysis
Reported Waterborne Outbreaks in Drinking Water for the 30-Year Period, 1971 to 2000

Epidemiologic Burden Measure	Value Used in the Burden Analysis	Reported or Estimated
Cases	569,962	Reported
Person-Days of Illness	4,504,933*	Estimated
Physician Visits	41,985	Estimated
Emergency Room Visits	23,575	Estimated
Hospitalizations	5,915	Reported
Deaths	66	Reported

* If 3 days duration of illness is assumed for cryptosporidiosis occurring during the Milwaukee outbreak (i.e., the median duration ascertained from survey respondents), the Person-Days of Illness value changes to 2,086,933.

3. RESULTS: PROJECTED EPIDEMIOLOGIC BURDEN ESTIMATE OF REPORTED INFECTIOUS WATERBORNE OUTBREAKS BY SUMMARY CATEGORIES AND IMPACT OF THE MILWAUKEE OUTBREAK

The epidemiologic burden estimate is presented in this chapter by four summary categories: etiologic agent, water system type, water system deficiency and water source type. Comparisons within these same categories are reported in the biennial surveillance summaries of waterborne-disease outbreaks published in CDC's *Morbidity and Mortality Weekly Report*. We conducted these analyses to identify the specific divisions within the summary categories that have been associated with the largest epidemiologic burden. It should be noted that the quantified epidemiologic burden describes only a subset of the total epidemiologic burden associated with waterborne outbreaks. Due to the magnitude of illness associated with the Milwaukee WBDO, we developed additional comparisons within the summary categories by excluding the Milwaukee WBDO. This allowed for examination of trends that may be evidenced by data from the other 664 reported WBDOs.

3.1. EPIDEMIOLOGIC BURDEN ASSOCIATED WITH REPORTED WBDOs BY ETIOLOGIC AGENT

Etiologic agents were identified in only 45% of WBDOs reported to the WBDOSS. Over the 30-year period, protozoans caused the most outbreaks when the etiologic agent was identified. Protozoan agents were associated with the most cases (449,925), person-days ill (4,090,423), physician visits (29,949), emergency room visits (13,093), hospitalizations (4517) and deaths (50) (Table 3-1). The major contributors to the burden of protozoan WBDOs reported to WBDOSS were *Cryptosporidium* and *Giardia* (Table 3-2). Other protozoan agents (i.e., *Cyclospora* and *En. histolytica*) were reported in only one outbreak each and contributed little to the epidemiologic burden estimate.

AGI WBDOs (i.e., outbreaks with no identified etiologic agent) were associated with the second highest estimates of person-days ill, physician visits and emergency room visits; however, bacterial outbreaks were associated with more hospitalizations and deaths than AGI WBDOs (Table 3-1). Bacterial WBDOs resulted in about 25% more reported cases of illnesses than viral WBDOs (20,786 cases versus 15,758 cases). The major contributors to the burden of bacterial WBDOs were *Shigella*, *Campylobacter*, *E. coli* and non-typhoid *Salmonella* spp. (Table 3-2). When compared to viral WBDOs, bacterial WBDOs also resulted in larger estimates of person-days ill,

TABLE 3-1

Estimated Epidemiologic Burden of Reported Infectious Waterborne Outbreaks in Drinking Water by Etiologic Agent, 1971 to 2000*

Etiologic Agent	Outbreaks	Cases	Person-Days Ill	Physician Visits	Emergency Room Visits	Hospital-izations	Deaths
AGI	365	83,493	265,000	8,820	9,430	378	1
Viruses	56	15,758	53,700	2,020	124	92	0
Bacteria	101	20,786	95,600	1,200	931	928	15
Protozoa							
Milwaukee WBDO	1	403,000	3,630,000	20,300	11,700	4,400	50
All Other WBDOs	142	46,925	463,000	9,700	1,370	117	0
Total	665	569,962	4,500,000	42,000	23,600	5,915	66

* The outbreak, case number, hospitalization and death totals are summarized from WBDOSS. Column totals for person-days ill, physician visits and emergency room visits may not sum due to rounding.

TABLE 3-2

Estimated Epidemiologic Burden of Reported Infectious Waterborne Outbreaks in Drinking Water by Etiologic Agent, 1971 to 2000*

Etiologic Agent	Outbreaks	Cases	Person-Days Ill	Physician Visits	Emergency Room Visits	Hospital-izations	Deaths
AGI	365	83,493	265,000	8,820	9,430	378	1
Viruses							
Norovirus	26	13,100	25,100	1,090	43	10	0
SRSV (assumed to be norovirus)	1	70	9,690	6	0	0	0
Rotavirus	1	1,761	91	146	6	0	0
Hepatitis A	28	827	18,800	780	75	82	0
Bacteria							
C. jejuni	19	5,604	26,100	325	16	87	0
E. coli O157:H7 & other	12	1,529	10,500	89	7	122	4
E. coli O157:H7 *& Campylobacter*	1	781	60	45	4	71	2
P. shigelloides	1	60	210	3	0	3	0
Salmonella non-typhoid spp.	15	3,203	17,300	186	15	82	7

TABLE 3-2 cont.							
Etiologic Agent	Outbreaks	Cases	Person-Days Ill	Physician Visits	Emergency Room Visits	Hospital-izations	Deaths
S. enterica serovar Typhi	5	282	5,500	7	1	238	0
Shigella	44	9,196	31,100	533	886	301	2
V. cholerae	2	28	950	2	0	4	0
Yersinia	2	103	134	6	0	10	0
Protozoa							
Cryptosporidium							
Milwaukee WBDO	1	403,000	3,630,000	20,300	11,700	4,400	50
All Other WBDOs	14	18,473	171,000	929	538	48	0
Cyclospora	1	21	228	1	1	0	0
En. histolytica	1	4	3,750	0	0	1	0
Giardia	126	28,427	292,000	8,740	827	68	0
Total	665	569,962	4,500,000	42,000	23,600	5,915	66

* The outbreak, case number, hospitalization and death totals are summarized from WBDOSS. Column totals for person-days ill, physician visits and emergency room visits may not sum due to rounding.
AGI = Acute gastrointestinal illness of unknown etiology
SRSV = Small round structured virus

emergency room visits, hospitalizations and deaths (Table 3-1). However, viral WBDOs resulted in almost twice as many physician visits than bacterial WBDOs. Fifty-four percent of the physician visits associated viral WBDOs were due to norovirus (Table 3-2). In viral WBDOs, over half of the person-days ill were due to Hepatitis A which accounted for only 5% of the cases attributed to viral WBDOs.

Tables 3-1 and 3-2 show that the Milwaukee WBDO is, by far, the largest WBDO reported to the WBDOSS between 1971 and 2000. Table 3-1 shows that, for each epidemiologic burden measure, the Milwaukee WBDO is greater than the corresponding burden measure, reported for all other protozoan WBDOs, all AGI WBDOs, all bacterial WBDOs and viral WBDOs. In fact, this single outbreak accounted for more cases, person-days ill, emergency room visits, hospitalizations and deaths than all other WBDOs combined.

Excluding the Milwaukee WBDO, the types of pathogens that contributed the most to individual burden measures differ from those identified when Milwaukee is included. Table 3-1 shows that protozoan WBDOs still accounted for more person-days ill and physician visits than any other type of pathogen. Bacterial WBDOs accounted for more hospitalizations and 15 of the 16 reported deaths. The AGI WBDOs accounted for more cases and emergency room visits than any of the specific pathogens. Excluding the AGI and the Milwaukee WBDOs, Table 3-2 shows that *Giardia*, *Cryptosporidium* and norovirus accounted for the most cases of reported WBDOs; *Giardia*, *Cryptosporidium* and *Shigella* accounted for the most person-days ill. If AGI and the Milwaukee WBDOs are excluded, *Giardia*, norovirus, and *Cryptosporidium* accounted for the most physician visits; *Shigella*, *Giardia* and *Cryptosporidium* accounted for most of the emergency room visits. If AGI and the Milwaukee WBDOs are excluded, three bacterial WBDOs were associated with the most hospitalizations: *Shigella, S. enterica* serovar Typhi and *E. coli.* When the Milwaukee WBDO is excluded, bacterial WBDOs accounted for most of the remaining deaths; the primary agents that caused these deaths were non-typhoid *Salmonella* spp. and *E. coli* O157:H7.[1,2]

[1] Although most strains of *E. coli* are not pathogenic, there are a number of diarrheagenic strains. Of particular concern are the enterohemorrhagic strains such as O157:H7. The WBDOSS specifically identifies the nine *E. coli* outbreaks that have occurred since 1989 as strain O157:H7.

[2] The WBDOSS does not specifically identify any cases of hemolytic uremic syndrome (HUS), which has been linked to *E. coli* O157 infections. However, supplemental reports for 3 WBDOs listed 4, 12 and 2 HUS cases; these WBDOs resulted in 0, 2 and 1 deaths, respectively. These HUS cases have been noted in external reports describing some of the *E. coli* O157:H7 outbreaks included in the WBDOSS (Swerdlow et al., 1992; CDC, 1999b; Olsen et al., 2002). See Chapter 6 for further analysis of HUS.

3.2. EPIDEMIOLOGIC BURDEN BY WATER SYSTEM TYPE

In the WBDOSS, water systems are classified as community, non-community or individual (see Chapter 1 for more details).[3] For our projected burden estimates, all burden measures except the number of outbreaks were greatest for community systems; community systems accounted for the most cases (485,844), person-days ill (4,215,965), physician visits (32,400), emergency room visits (16,268), hospitalizations (4931) and deaths (62). Although non-community systems reported 75 more WBDOs than community systems (Table 3-3), all other summary measures were substantially less than those reported by community systems. Summary burden measures were the lowest for individual systems reflecting the low number of individual system outbreaks reported.

If the Milwaukee WBDO is excluded, Table 3-3 shows that the remaining community system WBDOs and the non-community WBDOs had comparable numbers of cases. Although the remaining community system WBDOs (i.e., excluding Milwaukee) had more than twice as many person-days ill and nearly 40% more physician visits than non-community system WBDOs, non-community system WBDOs had nearly 50% more emergency room visits and nearly 70% more physician visits than community system WBDOs. The 253 remaining community system WBDOs reported 12 deaths and the non-community system WBDOs reported four deaths.

Communities receive their drinking water from surface waters, groundwaters or a mix of the two. Table 3-4 shows the number of community system outbreaks that were associated with each type of water source. The table shows that surface water sources and groundwater sources have accounted for roughly the same number of community system WBDOs. Table 3-4 also shows that community system WBDOs that occurred in communities served by surface water systems have resulted in the largest number of person-days ill and deaths. When the Milwaukee WBDO is excluded from the analysis, WBDOs in community systems served by groundwater accounted for the remaining 12 deaths that occurred in community systems; however, groundwater sources accounted

[3] Community and non-community water systems are public water systems that serve >15 service connections or an average of >25 residents for >60 days/year. A community water system serves year-round residents of a community, subdivision or mobile home park with >15 service connections or an average of >25 residents. A non-community water system can be nontransient or transient. Non-transient systems serve >25 of the same persons for >6 months of the year, but not year-round (e.g., factories or schools), whereas transient systems provide water to places in which persons do not remain for long periods of time (e.g., restaurants, highway rest stations, parks, etc.). Individual water systems are small systems not owned or operated by a water utility that serve <15 connections or <25 persons. Outbreaks associated with water not intended for drinking (e.g., lakes, springs and creeks used by campers and boaters, irrigation water and other non-potable sources with or without taps) are also classified as individual systems.

TABLE 3-3

Estimated Epidemiologic Burden of Reported Infectious Waterborne Outbreaks in Drinking Water, 1971 to 2000*

Water System Classification	Outbreaks	Cases	Person-Days Ill	Physician Visits	Emergency Room Visits	Hospital-izations	Deaths
Community							
Milwaukee WBDO	1	403,000	3,630,000	20,300	11,700	4,400	50
All Other WBDOs	253	82,844	589,000	12,100	4,540	531	12
Non-Community	329	78,703	262,000	8,810	6,740	885	4
Individual	82	5,415	26,700	773	563	99	0
Total	665	569,962	4,500,000	42,000	23,600	5,915	66

* The outbreak, case number, hospitalization and death totals are summarized from WBDOSS. Column totals for person-days ill, physician visits and emergency room visits may not sum due to rounding.

TABLE 3-4

Select Epidemiologic Burden Measures for Community System Outbreaks by Source Water Types, n=254

Source Water	Outbreaks	Person-Days Ill (nearest 1000)	Deaths
Surface Water	117	4,034,000	50
Groundwater	110	146,000	12
Unknown	23	20,000	0
Mixed	4	15,000	0

for only 25% of the person-days ill in community system WBDOs because the remaining surface water WBDOs accounted for nearly 70% of the person-days ill.

3.3. EPIDEMIOLOGIC BURDEN BY WATER SYSTEM DEFICIENCY

WBDOs are categorized in the surveillance system according to the deficiency that may have caused or contributed to the outbreak (see Chapter 1 and Appendix A). The five major categories are water treatment deficiencies; distribution system deficiencies; untreated, contaminated groundwater; untreated, contaminated surface water; miscellaneous and unknown deficiencies. The most important contributor to the projected epidemiologic burden for all measures was one or more water treatment deficiencies (Table 3-5). WBDOs attributed to one or more water treatment deficiencies accounted for the most outbreaks (269), cases (525,733), person-days ill (4,281,583), physician visits (36,348), emergency room visits (20,068), hospitalizations (4980) and deaths (52). The next two most important contributors to the epidemiologic burden associated with outbreaks reported to the WBDOSS were distribution system deficiencies and the use of untreated, contaminated groundwater. Although more WBDOs in untreated groundwater systems were reported to the WBDOSS, the other epidemiologic burden measures were roughly equivalent (i.e., same order of magnitude). The lowest epidemiologic burden was associated with WBDOs attributed to miscellaneous or unknown deficiencies or untreated surface water. U.S. EPA regulations now prohibit the use of untreated surface water for community and non-community water systems (U.S. EPA, 2003). Regulations pertaining to groundwater are currently under development.

If the Milwaukee WBDO is excluded from the analysis, Table 3-5 shows that the remaining WBDOs attributed to water treatment deficiencies account for more outbreaks, cases, person-days ill, physician visits, emergency room visits and hospitalizations than all other types of deficiencies. However, outbreaks due to distribution system deficiencies had more deaths (12) reported to the WBDOSS than the remaining outbreaks caused by one or more water treatment deficiencies (2), untreated groundwater (2), untreated contaminated surface water (0), miscellaneous (0) and unknown deficiencies (0). Outbreaks due to untreated groundwater resulted in the second highest number of outbreaks, cases, physician visits, emergency room visits and hospitalizations, but distribution system deficiencies accounted for the second highest levels of reported person-days ill and deaths.

TABLE 3-5

Estimated Epidemiologic Burden of Reported Infectious Waterborne Disease Outbreaks in Drinking Water by Water System Deficiency, 1971 to 2000*

Deficiency	Outbreaks	Cases	Person-Days Ill	Physician Visits	Emergency Room Visits	Hospital-izations	Deaths
Deficiency in Water Treatment							
Milwaukee WBDO	1	403,000	3,630,000	20,300	11,700	4,400	50
All Other WBDOs	268	122,733	655,000	16,100	8,340	580	2
Distribution System Deficiency	83	15,305	98,300	2,310	824	201	12
Untreated Groundwater	211	22,285	83,800	2,610	2,220	602	2
Miscellaneous	41	2,053	14,900	223	193	43	0
Unknown Deficiency	23	3,372	16,600	291	173	84	0
Untreated Surface Water	38	1,214	9,710	208	100	5	0
Total	665	569,962	4,500,000	42,000	23,400	5,915	66

* The outbreak, case number, hospitalization and death totals are summarized from WBDOSS. Column totals for person-days ill, physician visits and emergency room visits may not sum due to rounding.

The fewest number of outbreaks were attributed to the following three types of deficiencies: miscellaneous (41), untreated contaminated surface water (38) and unknown deficiencies (23); no deaths were reported for any WBDOs attributed to these deficiencies. Of these three types of deficiencies identified in the reported WBDOs, untreated contaminated surface waters reported the fewest numbers of cases, person-days ill, physician visits, emergency room visits and hospitalizations. Despite causing the smallest number of outbreaks, WBDOs attributed to unknown deficiencies had the highest number of cases, hospitalizations, physician visits and person-days ill. The number of emergency room visits for WBDOs attributed to miscellaneous causes were higher than for those attributed to unknown deficiencies.

Figures 3-1 through 3-4 illustrate the person-days ill associated with each etiologic agent for each type of deficiency. Figure 3-1a shows that *Cryptosporidium* accounted for most (88%) of the person-days ill associated with water treatment deficiencies; over 95% of these person-days ill associated with *Cryptosporidium* occurred during the Milwaukee WBDO. We note that this single outbreak also was associated with most of the deaths reported in the WBDOSS. Figure 3-1b shows that, if the Milwaukee WBDO is excluded from the analysis, *Giardia* (36%), AGI (27%) and *Cryptosporidium* (24%) accounted for nearly 86% of the person-days ill that occurred due to water treatment deficiency. Figure 3-2 shows that *Giardia* (54%) accounted for over half of the person-days ill for WBDOs attributed to distribution system deficiencies. Outbreaks attributed to AGI (22%) and *Salmonella* (12%) combined accounted for 34% of the estimated person-days ill associated with distribution system deficiencies. Previously, we reported that outbreaks attributed to distribution system deficiencies were associated with 12 (18%) of the deaths reported in the WBDOSS. Non-typhoid *Salmonella* spp. (7) and *E. coli* (4) accounted for most of these deaths. Outbreaks associated with AGI accounted for 65% of the person-days ill when the cause of the outbreak was attributed to untreated groundwater (Figure 3-3). Outbreaks associated with Hepatitis A, the most frequently identified etiologic agent, accounted for 15% of all person-days ill. The two deaths caused by untreated groundwater were associated with an *E. coli* and *Campylobacter* outbreak.

The epidemiologic burden associated with the remaining outbreak deficiencies reported in the WBDOSS is substantially smaller than the burden associated with treatment deficiencies, distribution system deficiencies and untreated groundwater. When the cause of the outbreak was attributed to untreated surface water, *Giardia* (46%) and AGI (38%) accounted for 84% of all person-days ill (Figure 3-4).

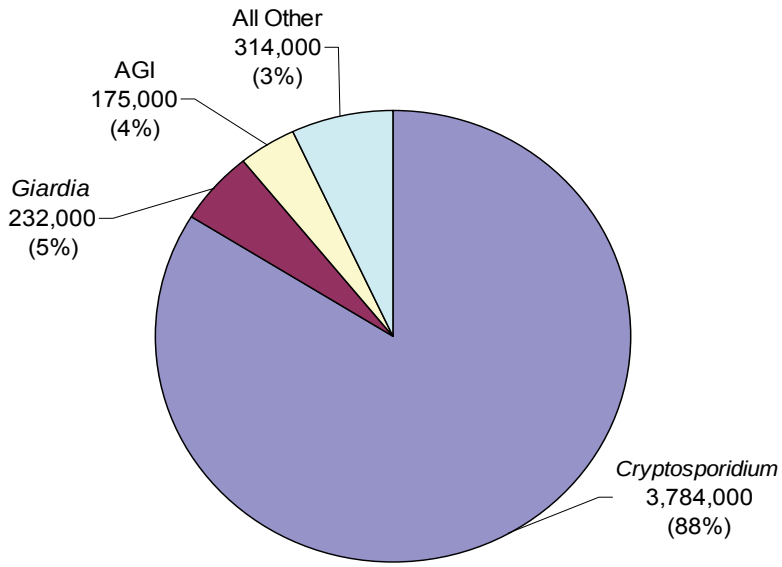


FIGURE 3-1a

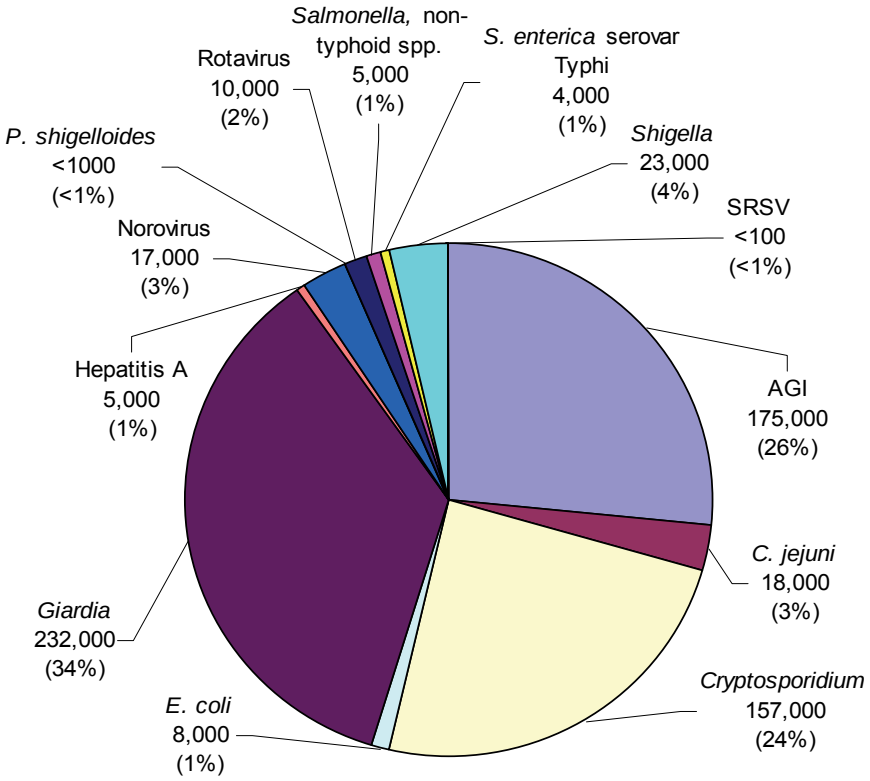


FIGURE 3-1b

Estimated Person-Days Ill for Waterborne Outbreaks Attributed to Deficiency in Water Treatment by Etiologic Agent* (Figure 3-1a includes the Milwaukee Outbreak and Figure 3-1b excludes the Milwaukee Outbreak)

* Percentages differ slightly from those listed in text due to rounding.

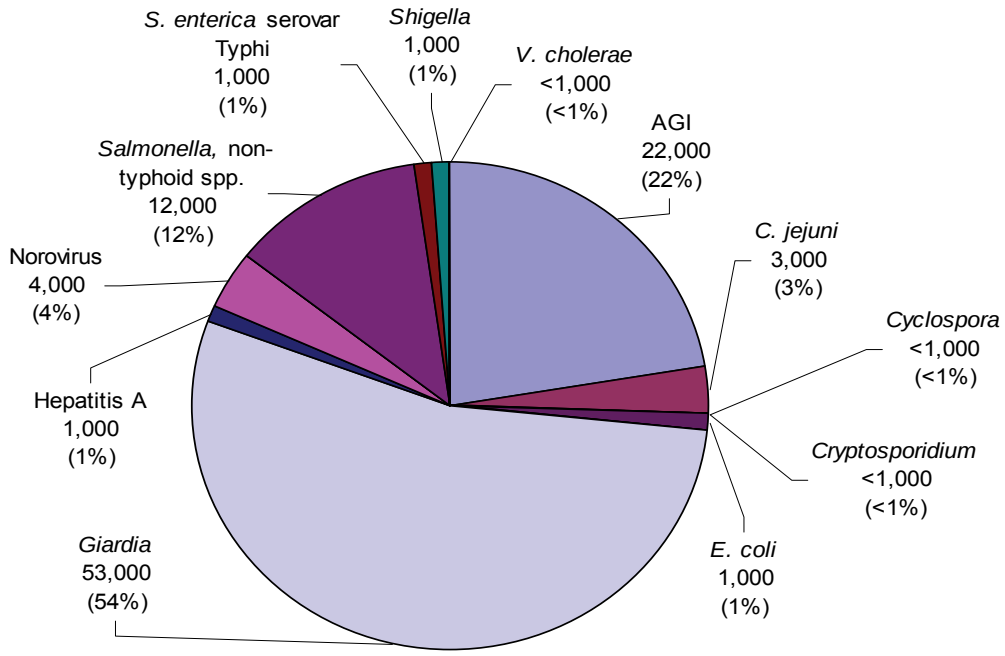


FIGURE 3-2

Estimated Person-Days Ill for Waterborne Outbreaks Attributed to Distribution System Deficiency

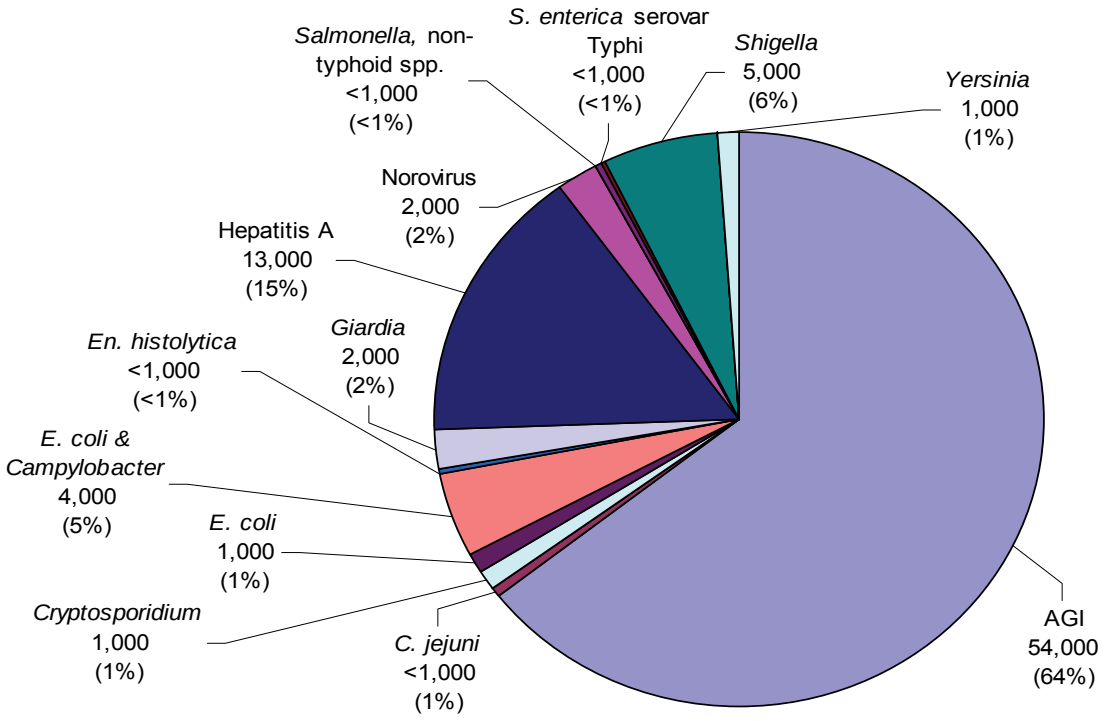


FIGURE 3-3

Estimated Person-Days Ill for Waterborne Outbreaks Attributed to Untreated Groundwater

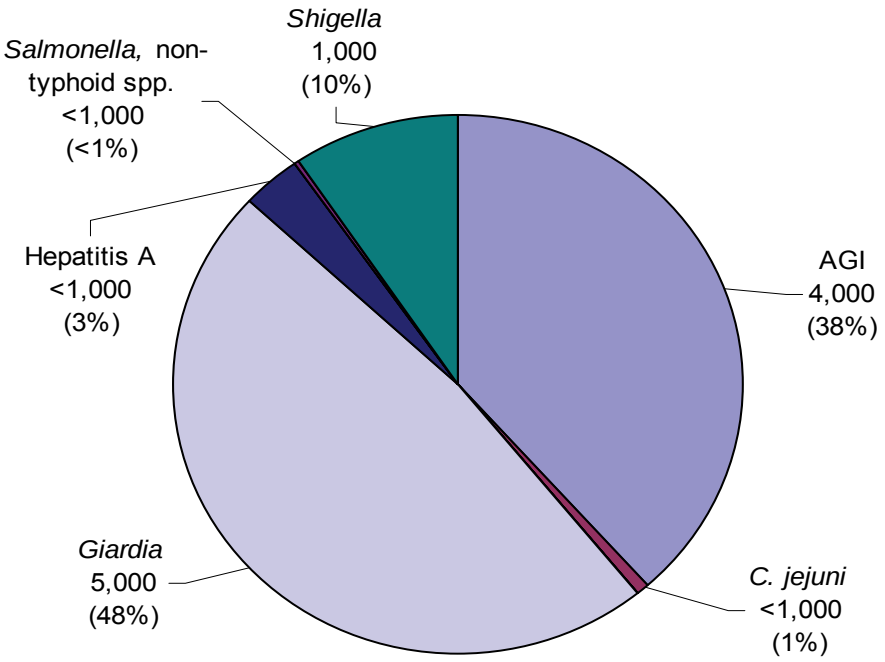


FIGURE 3-4

Estimated Person-Days Ill for Waterborne Outbreaks Attributed to Water System Deficiency in Untreated Surface Water

3.4. EPIDEMIOLOGIC BURDEN BY WATER SOURCE TYPE

WBDOs occurring in surface water systems were reported in the WBDOSS less frequently than in groundwater systems (183 versus 425), but WBDOs in surface water systems experienced a greater number of cases (457,310), person-days ill (4,058,221), physician visits (29,735), emergency room visits (14,443), hospitalizations (4644) and deaths (50) (Table 3-6). Most of the surface water outbreaks were associated with *Giardia* (48%) or AGI (36%) (Figure 3-5). However, most of the person-days ill in surface water outbreaks were associated with *Cryptosporidium* (92%), primarily due to the Milwaukee WBDO, which accounted for over 89% of all person-days ill associated with *Cryptosporidium* (Figure 3-6). Groundwater outbreaks were primarily associated with AGI (62%) (Figure 3-7). AGI outbreaks were responsible for the greatest number of person-days ill in groundwater systems (52%) (Figure 3-8). Unknown and mixed water sources were negligible contributors to the epidemiologic burden estimate.

3.5. OVERALL IMPACT OF MILWAUKEE CRYPTOSPORIDIOSIS OUTBREAK

The Milwaukee WBDO contributed a significant portion of the projected epidemiologic burden for WBDOs reported to the WBDOSS, and therefore, the epidemiologic burden estimates are highly sensitive to the severity measures reported in Milwaukee. This WBDO contributed 403,000 (71%) cases of illness, 3,627,000 (81%) person-days ill, 20,280 (48%) physician visits, 11,727 (50%) emergency room visits, 4400 (74%) hospitalizations and 50 (76%) deaths to the projected burden. Consequently, the summary burden categories associated with this WBDO (community water systems, protozoan agents, *Cryptosporidium*, water treatment deficiencies) have the highest burden. This demonstrates the impact that a very large WBDO can have on the epidemiologic burden.

3.6. FURTHER ANALYSIS OF OUTBREAKS CAUSED BY AGI

WBDOs attributed to AGI contributed significantly to the epidemiologic burdens for the reported WBDO. Because these outbreaks could be caused by different organisms, we stratified the AGI WBDOs across source water and system type. Figure 3-9a shows that 72% of the outbreaks attributed to AGI have occurred in systems served by groundwater sources. Figure 3-9b shows that these groundwater WBDOs accounted for 81% of the person-days ill attributed to the AGI. This suggests that WBDOs occurring in groundwater sources may be caused by etiologic agents that are difficult to detect (e.g., viruses). Figures 3-9c and 3-9d show that non-community systems accounted for over 60% of the outbreaks and the person-days ill attributed to

TABLE 3-6

Estimated Epidemiologic Burden of Reported Infectious Waterborne Outbreaks in Drinking Water by Water Source Type, 1971 to 2000*

Water Source Type	Outbreaks	Cases	Person-Days Ill	Physician Visits	Emergency Room Visits	Hospitalizations	Deaths
Surface Water							
Milwaukee WBDO	1	403,000	3,630,000	20,300	11,700	4,400	50
All Other WBDOs	182	54,310	431,000	9,460	2,720	244	0
Groundwater	425	105,750	407,000	11,500	8,390	1,208	16
Unknown	51	3,997	23,700	460	518	43	0
Mixed	6	2,905	15,900	330	227	20	0
Total	665	569,962	4,500,000	42,000	23,600	5,915	66

* The outbreak, case number, hospitalization and death totals are summarized from WBDOSS. Column totals for person-days ill, physician visits and emergency room visits may not sum due to rounding.

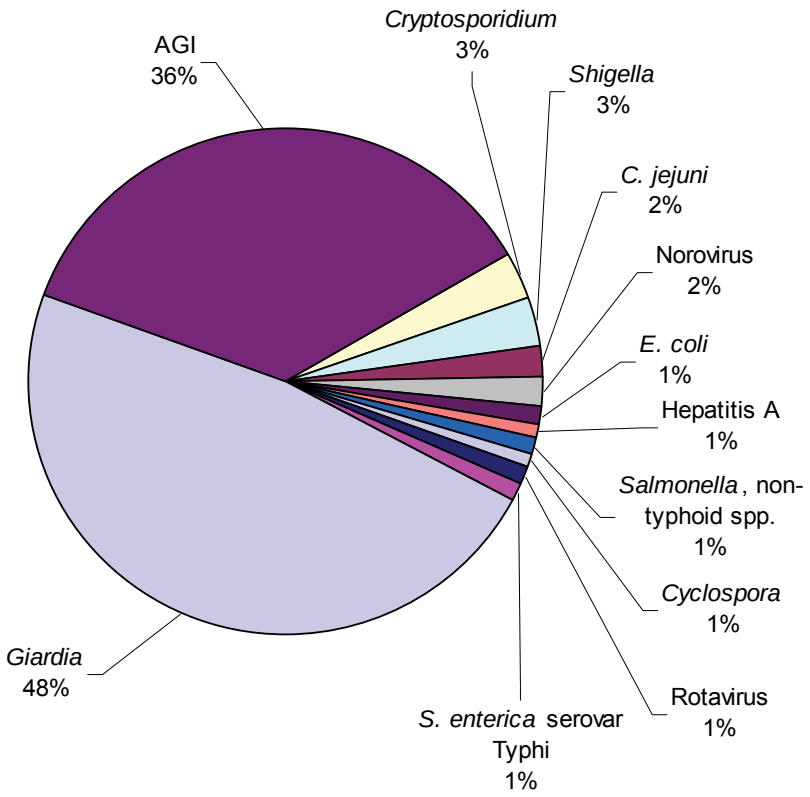


FIGURE 3-5

Pathogens Associated with Waterborne Outbreaks Reported in Surface Water Systems

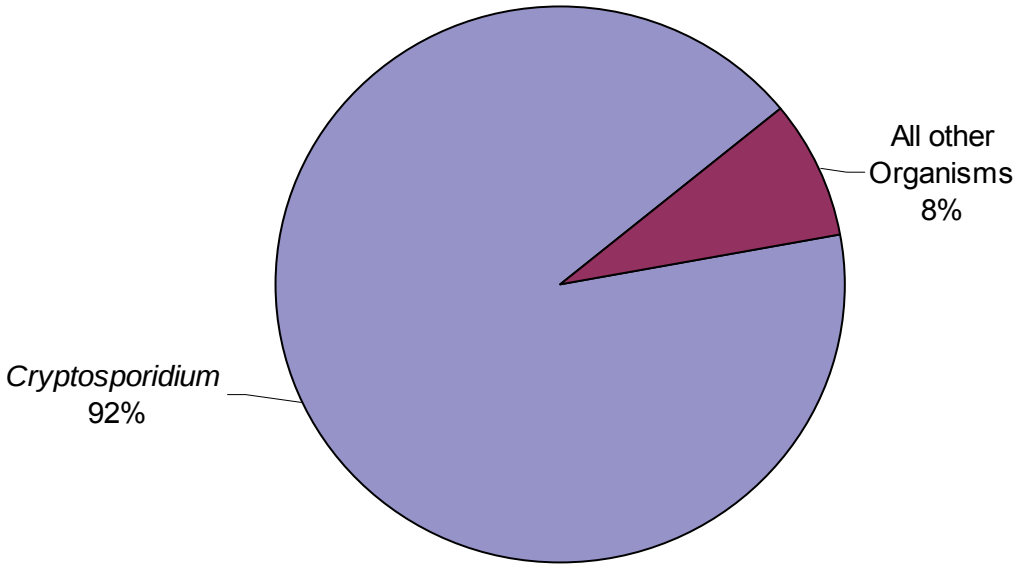


FIGURE 3-6

Pathogens Associated with Estimated Person-Days Ill Reported in Surface Water System Outbreaks (The Milwaukee Outbreak accounted for 89%)

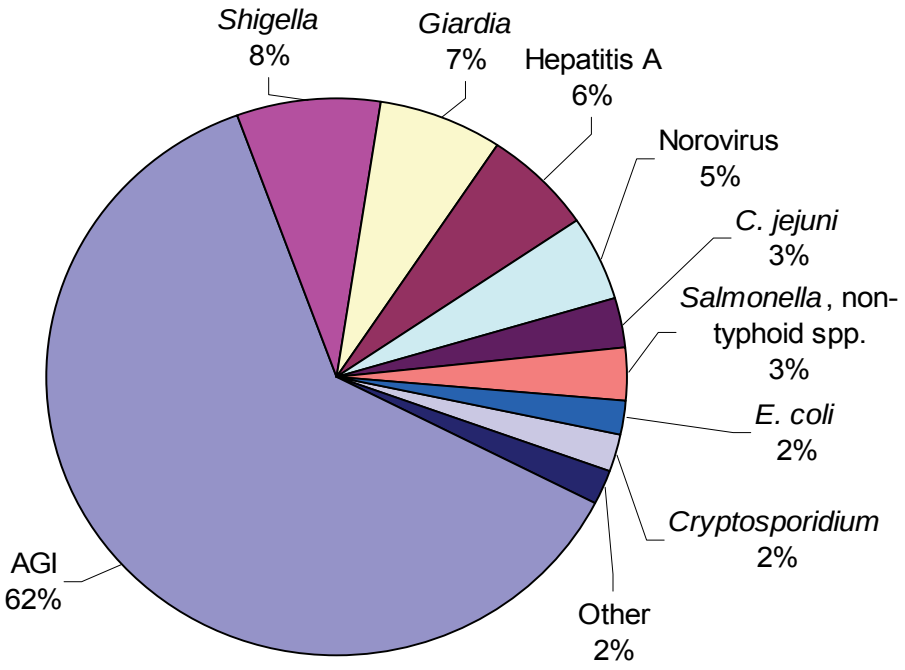


FIGURE 3-7

Pathogens Associated with Waterborne Outbreaks Reported in Groundwater Systems

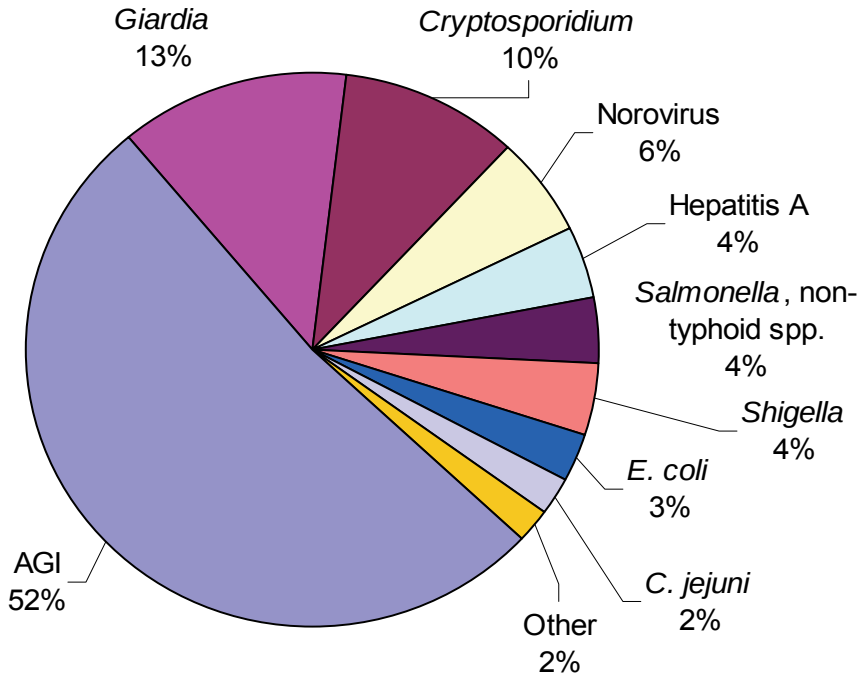
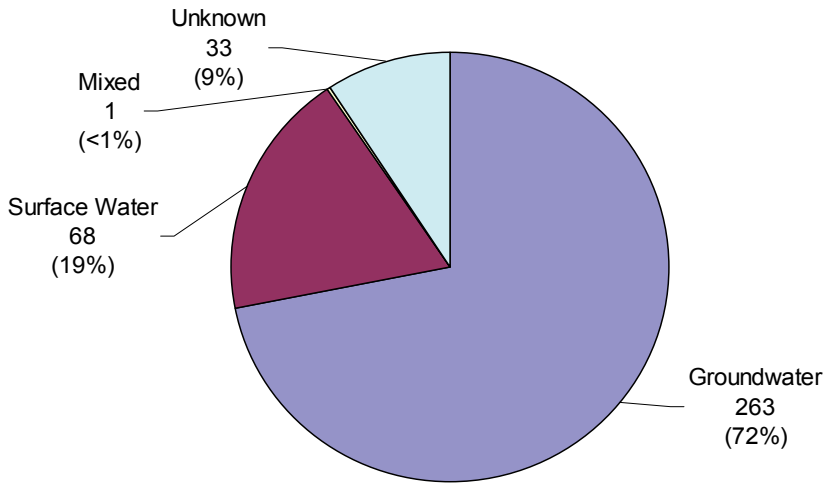
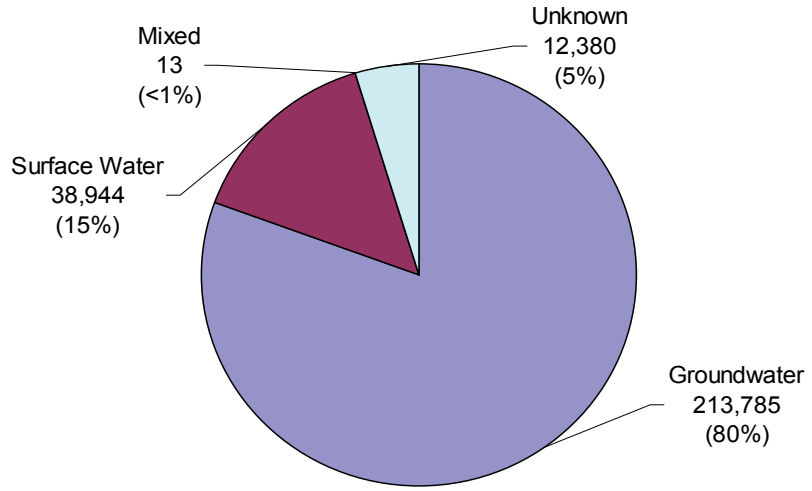


FIGURE 3-8

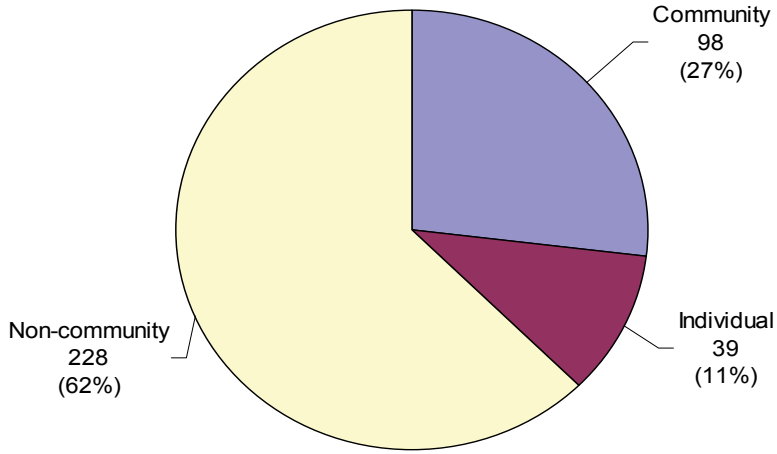
Pathogens Associated with Estimated Person-Days Ill in Waterborne Outbreaks that Occurred in Groundwater Systems



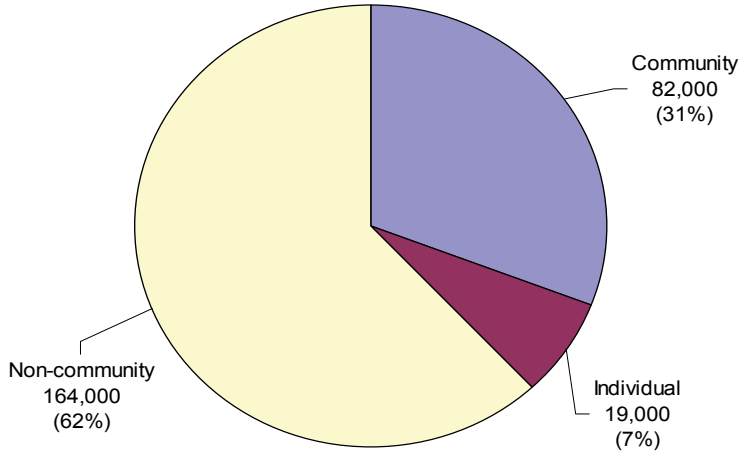
3-9a. Number of AGI WBDOs by Source Water Type



3-9b. Estimated Number of Person-Days Ill for AGI WBDOs by Source Water Type



3-9c. Number of AGI WBDOs by Water System Type



3-9d. Estimated Number of Person-Days Ill for AGI WBDOs by Water System Type

Figure 3-9

Burden Attributed to AGI Outbreaks by Water Source and System

AGI. This suggests that it is more difficult to identify an etiologic agent in WBDOs that occur in non-community systems than those WBDOs that occur in other systems.

3.7. DISCUSSION AND CONCLUSIONS

When comparing multiple epidemiologic burden measures for the various water system categories, it is not always clear which category makes the most important contribution to the overall burden. In some analyses, one category may be an important contributor to most but not all burden measures. For example, when analyzing the projected epidemiologic burden by etiologic agent group we found that AGI WBDOs were associated with more outbreaks, cases, person-days illness and physician visits than bacterial WBDOs, but bacterial WBDOs were associated with more hospitalizations and deaths. In order to rank the various summary measures by their relative importance, a weighting approach of the burden severity measures should be considered. In Chapters 4 and 5, we present an economic weighting for some of these burden measures. Because the economic measures were developed using the same unit (dollars), they can be summed, allowing the various severity measures to be combined into a single severity expression—the monetary burden. The methodology for determining the monetary burden is described in Chapter 4, and a summary of the monetary burden measures for the WBDOs is provided in Chapter 5.

4. ECONOMIC METHODS FOR ESTIMATING DISEASE BURDEN ASSOCIATED WITH INFECTIOUS WATERBORNE OUTBREAKS

As stated in Chapter 1, disease burden can be estimated by epidemiologic measures (e.g., person-days ill or number of deaths) or summary population health measures (e.g., Disability Adjusted Life Years [DALYs]), cost-of-illness (COI) and willingness-to-pay (WTP). These measures can capture different dimensions of the impact of microbial illness, such as premature mortality, pain and suffering, economic losses to society and individuals and any other intangibles that society values. Some of the measures allow for comparisons of outbreaks and illnesses that impact these dimensions in different ways (e.g., the economic approaches based on WTP or COI). Corso et al. (2003), for example, estimate the medical costs and lost productivity associated with an outbreak of cryptosporidiosis using COI. Harrington et al. (1989) and Kocagil et al. (1998) estimate lower-bound WTP[1] because they include medical costs, lost productivity, defensive or averting expenditures and, in the case of Kocagil et al., premature mortality.

In this report we used a COI approach to estimate the monetary burden from morbidity measures reported to the waterborne disease outbreak surveillance system (WBDOSS). The COI approach is used as a proxy for estimating WTP because few WTP studies address waterborne disease outbreaks (WBDOs). The approach is consistent with our model of consumer welfare (see Section 1.3; Freeman, 1993; and U.S. EPA, 2000b) and with U.S. EPA standard practice (see Section 1.3.1 and U.S. EPA, 2000b, 2006a).

We chose not to estimate the monetary burden from mortality. The value of a statistical life (VSL) is one approach to estimate the monetary burden from mortality. It is based on WTP and estimates individuals' collective preferences for trade-offs between avoiding premature mortality and wealth (Hammitt, 2000; U.S. EPA, 2000a). Essentially, VSL estimates are based on individuals' choices and they reveal the value of avoiding one generic individual's premature death (not an actual death) in the future (see Section 1.3.3). Since the WBDOSS database includes actual deaths reported for waterborne outbreaks, this would not be consistent with a VSL approach (see Section 1.3.3 for more information).

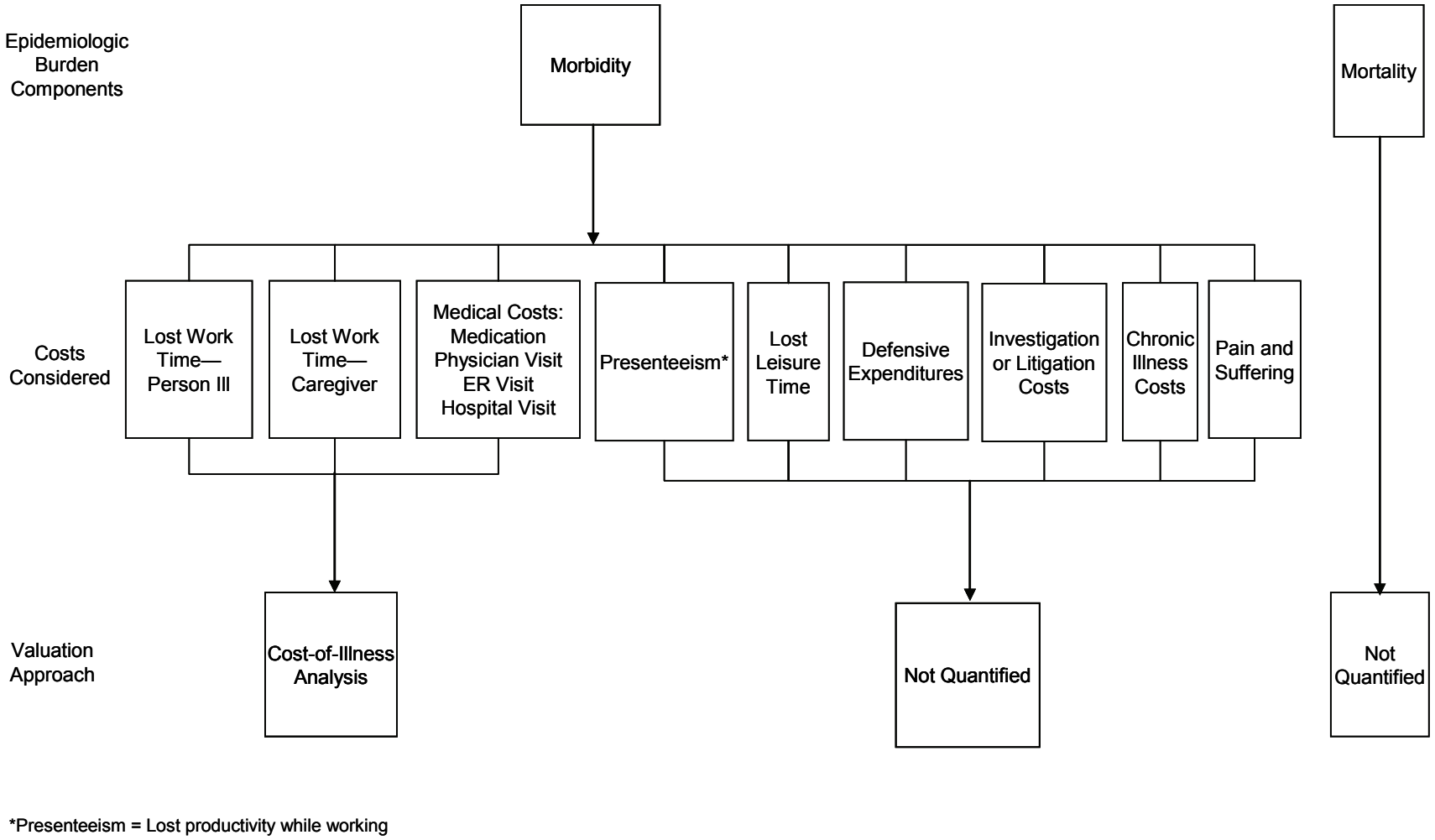
[1] The results from Harrington et al. (1989) and Kocagil et al. (1998) are considered lower-bound estimates of WTP because they do not capture dimensions such as pain and suffering. Many people place a positive value (i.e., would pay or undertake actions to) on avoided pain and suffering.

COI approaches also can be used to estimate the monetary burden from mortality. Traditionally, in COI studies, the primary cost associated with premature mortality is based on an individual's expected future earnings had they remained alive until some average age of death (e.g., the discounted product of age-adjusted life expectancy and annual income). This estimate is consistent with other components of the COI, in that it represents the monetary costs incurred by society; however, it is not consistent with Agency protocol (Whitman, 2003). Therefore, no attempt is made to estimate the monetary burden from mortality in this report.

In this chapter, we discuss the methods used to estimate the monetary burden associated with infectious WBDOs. The approach presented is applied only to the number of reported cases for each WBDO. In Section 4.1, we describe the COI approach, including the basis for estimating costs for self-medication, emergency room visits, hospitalizations and lost productivity (i.e., morbidity costs). In Section 4.2, we provide an estimate of the monetary burden of the WBDOs.

Figure 4-1 outlines the components we used to calculate the monetary burden; it also illustrates the components that we did not quantify. Additional categories of burden that are considered beyond the scope of this analysis include health effects to children and chronic illness associated with both bacterial and viral illness. We argue that other costs, for example, to the private sector are not consistent with the COI approach. Therefore, impacts to tourism and local and state governments will not be included in this analysis. The results of the COI analysis for morbidity are used as an estimate of the monetary burden presented in Chapter 5. COI measures are limited because they do not capture all aspects of disease burden such as pain and suffering, anxiety or lost leisure time. Expressing the burden in terms of epidemiologic units (Chapters 2 and 3) and monetary units through the COI approach (Chapters 4 and 5) allows us to estimate the enteric disease burden associated with reported WBDOs from two different perspectives.[2] This provides an opportunity to compare the burden among the various etiologic agents, water system types and system deficiencies.

[2] Epidemiologic units are the basis of the COI estimates developed for each WBDO. Uncertainties in the estimation of the aggregated epidemiologic units will be propagated through the subsequent analysis.



*Presenteeism = Lost productivity while working

FIGURE 4-1

Illustration of the Components for Monetary Burden Calculations
(Adapted from U.S. EPA, 2000c)

4.1. ESTIMATING THE MONETARY BURDEN OF WBDO USING COST-OF-ILLNESS APPROACH

An outbreak can have a substantial economic impact on a community. Using cost estimates, such as those from Corso et al. (2003), we compare monetary burden associated with WBDOs. We then compare the monetary burden associated with different pathogens or different outbreak causes, such as treatment failure or contaminated source water. Other applications using monetary measures, such as examining the efficiency of regulations or management alternatives, typically require additional information and assumptions; these are not evaluated in this report.

The COI approach measures direct medical costs and indirect costs such as productivity losses due to temporary ailments (Rice, 1967). The direct medical costs include medication (Section 4.1.2), physician visits (Section 4.1.3), emergency room visits (Section 4.1.4) and hospital stays (Section 4.1.5). The loss of productivity of the average person is assumed to be days lost based on a fraction of the duration of illness (Section 4.1.6).

The COI of the j^{th} outbreak could be calculated by summing the costs of each case, dependent on cost related to self-medication (e.g., over-the-counter medications), physician visits, emergency room visits, hospitalizations and productivity losses of the ill person and their caregiver(s) (e.g., family members). However, because this type of data is not recorded in the database, calculating COI at the individual level is not feasible. Alternatively, the COI of the j^{th} outbreak can be estimated by using mean values reported for other outbreaks (Equation 4-1).

$$COI_j = (N_{ill} x C_{SM}) + (N_{PV} x C_{PV}) + (N_{ER} x C_{ER}) + (N_H x C_{HP}) + \sum_{s=1}^{3} [(P_{PIs} x D_s x L_D) + (P_{PCGs} x D_s x L_D)]$$

$$= SM_j + PV_j + ER_j + H_j + PI_j + PCG_j \qquad \text{(Eq. 4-1)}$$

where:

N_{ill} = Number of ill persons

C_{SM} = Mean cost of self-medication (2000$)

N_{PV} = Number of physician visits

C_{PV} = Mean cost of physician visit (2000$)

N_{ER} = Number of emergency room visits

C_{ER} = Mean cost of emergency room visit (2000$)

N_H = Number of hospitalizations

C_{HP} = Mean cost of hospitalizations for specific pathogens (2000$)

P_{PI} = Percent days lost for each severity category (based on fraction of duration) for ill persons multiplied by number of persons in each severity category

P_{PCG} = Percent days lost for each severity category (based on fraction of duration) for caregivers multiplied by number of persons in each severity category

D = Duration (Days)

L_D = Value of a lost day (2000$)

s = Severity categories: mild, moderate and severe

SM_j = Total cost of self-medication purchased to treat illness associated with the jth outbreak (2000$)

PV_j = Total cost of physician visits associated with the j^{th} outbreak (2000$)

ER_j = Total cost of emergency room visits associated with the j^{th} outbreak (2000$)

H_j = Total cost of hospitalizations associated with the j^{th} outbreak (2000$)

PI_j = Productivity losses of ill persons associated with the j^{th} outbreak (2000$)

PCG_j = Productivity losses of caregivers associated with the j^{th} outbreak (2000$).

By using estimated mean values for the morbidity costs,[3] this equation does not capture important sources of cost variability between cases and across different outbreaks (see Table 4-1).

The definitions and calculations from Equation 4-1 are based largely on the economic analysis of the 1993 Milwaukee *Cryptosporidium* outbreak (Mac Kenzie et al., 1994; Corso et al., 2003). The majority of COI measures (SM, PV, ER, PI and PCG) were estimated using the Corso et al. (2003) approach. Corso and colleagues based their measures of COI on a telephone survey of Milwaukee residents by Mac Kenzie et al. (1994), which allowed for the categorization of cases based on severity. Corso et al.

[3]All cost estimates are adjusted to 2000 U.S. dollars (2000$) using the consumer price index (CPI) for medical care. The CPI is the average change in prices over time for a market basket of goods and services (in this case medical goods and services such as prescription drugs and medical supplies, physicians' services, and hospital services). It is typically used to measure inflation, but can also be used to develop comparisons using constant monetary units (U.S. Department of Labor, 2000).

TABLE 4-1

Parameter Estimates from Cost-of-Illness Studies (cost estimates adjusted to 2000$)

Components	Corso et al. (2003)	U.S. EPA's LT2ESWTR (2006a)	Kocagil et al. (1998)	Harrington et al. (1991)	Zimmerman et al. (2001)
Pathogen	*Crypto-sporidium*	*Crypto-sporidium*	*Crypto-sporidium*	*Giardia*	Rotavirus
Physician Visits	$58	$58	--	$88	$62[a]
Hospital Visits	$8,142	$7,937[b]	$12,419[c]	$244	$2,487[d]
ER Visits	$289	$289	$197[e]	$66	--
Medication	$12, $91[f]	$91	$2[g]	$68[h]	---
Lost Work Time	$206[i]	$88[j]	--	$876[k]	--
Presenteeism	--	$27[j]	--	$905[k]	--
Length of Illness (days)	--[l]	4.7, 9.4, 34[m]	--	42 (mean)	--
Work Loss Days	1.3, 3.8, 13.5[n]	1.3, 3.8, 13.5[n]	--	6.3, 12.7[o]	--

[a] Median cost of rotavirus-associated outpatient visit.
[b] Based on Corso et al. (2003), 71% of severe illness patients that visited the ER were hospitalized. U.S. EPA (2006a) removed these ER costs from their hospitalization cost estimate.
[c] Medical expenditures for severe illness (i.e., hospitalization).
[d] Median cost of rotavirus-associated hospitalization.
[e] Medical expenditures for physician visit or ER visit.
[f] Cost of medication prescribed after seeking healthcare—moderate illness and severe illness, respectively (self-medication prior to seeking healthcare can be found in Table 4-4).
[g] Over-the-counter medications.
[h] Medication costs associated with medical treatment.
[i] Average cost of productivity losses across illness severity (mild, moderate and severe) where average productivity losses were $113, $413 and $1409 in 1993$, respectively. This value also includes the value of those who are not employed.
[j] Per day value includes both lost work time and lost unpaid work time and is calculated from U.S. EPA's enhanced COI analysis. Loss of work productivity is calculated as a portion (30%) of lost work time.
[k] Average per confirmed case evaluated at the implicit after-tax wage rate of the unemployed, homemakers and retirees equal to $6.39 per hour (average after-tax wage rate of employed) (Harrington et al., 1989, 1991).
[l] Corso et al. (2003) does not estimate a mean duration of illness for moderate or severe illness. The duration of illness for mild cases was estimated as 4.7 days.
[m] The U.S. EPA (2006a), using Monte Carlo analysis, calculated the mean duration of illness for moderate and severe illness. Corso et al. (2003) only has an estimate for mild cases.
[n] Mild, moderate and severe illness, respectively.
[o] Employed and homemakers, respectively.

TABLE 4-1 cont.

Components	Cohen et al. (1978) Foodborne	ERS Calculator (2006) Foodborne	AGA (2001) Foodborne	AGA (2001) Chronic diarrhea	Ezzati-Rice et al. (2004)
Pathogen	*Salmonella*	*Salmonella*	All	All	All expenses
Physician Visits	$699[p]	$93	$114	$123	--
Hospital Visits	$8,785[q]	$11,966	$5,848[r]	$2,453[r]	$5,195, $10,917[s]
ER Visits	--	$262	$350	$255	$315, $594[s]
Medication	--	0	--	--	--
Lost Work Time	$1,421[t]	$191,$186, $185[u]	--	--	--
Presenteeism	--	--	--	--	--
Length of Illness (days)	--	--	--	--	--
Work Loss Days	12, 3[v]	4.5, 1.6, 0.5[w]	--	--	--

[p] Study states that approximately 68% of $222 for outpatient visits (ER or office) is for medical care and the remainder is accounted for by estimates of lost productivity (based on assumption). Therefore, medical portion is $151 in 1976$.
[q] Includes physician fees, operations and medication.
[r] Comprised of two parts: (1) facility costs and (2) physician visits and procedures.
[s] Median, mean, respectively, per person with expense.
[t] Study determined each worker's daily salary and multiplied it by days of work lost (average of both employed and caregivers).
[u] Average daily wage rate depending on severity Severity categories, hospitalized, sought medical care, and did not seek medical care, respectively, were assumed to have different age distributions leading to different average daily wage rates.
[v] Average lost work days for employed patients (102 of 117 employed patients) and caregivers (39 of 102), respectively.
[w] Hospitalized, sought medical care and did not seek medical care, respectively.

also collected primary data from the medical and financial records of 11 hospitals in Milwaukee. We based our approach on Corso et al. because

- the Milwaukee outbreak represents almost 71% of all cases of illness reported in WBDOs during 1971-2000;
- the economic analysis is fairly recent; and
- the analysis is presented in sufficient detail for our use.[4]

However, they did not include averting behavior costs or defensive expenditures (e.g., purchasing a water filter or bottled water), costs of epidemiologic investigation or litigation nor did they consider pain and suffering. Therefore, the COI estimates for this analysis do not either.[5]

Specific assumptions are highlighted in each section where the Corso et al. analysis was used. Our COI analysis is limited because we estimated disease burden using the same process regardless of year; we assumed that medical treatment administered and costs for gastrointestinal illnesses have remained constant across years.

For comparison purposes, general economic analyses are reported in Table 4-1. Besides Corso et al. (2003), we present nine other COI studies. U.S. EPA (2006a), expanding on Corso et al., analyzed the effects of the Long Term 2 Enhanced Surface Water Rule. Kocagil et al. (1998) focused on Lancaster County, PA to estimate the value of preventing a *Cryptosporidium* contamination event. Harrington et al. (1991) examined the economic losses caused by waterborne giardiasis in Luzerne County, PA. Zimmerman et al. (2001) calculated costs for rotavirus-associated hospitalizations and outpatient visits for privately insured children during the period of 1993 to 1996. Cohen et al. (1976) analyzed the economic costs of a foodborne outbreak of salmonellosis (due to non-typhoid *Salmonella* spp.) in Colorado. The Economic Research Service (ERS, 2006) of the U.S. Department of Agriculture calculated the costs of different foodborne illnesses. We present their cost estimates for salmonellosis. The last three studies are not specific to any particular pathogen. The American Gastrointestinal Association (AGA) calculated the economic costs for common disorders. We included

[4] For analyses of specific outbreaks, values which are specific to the area of the outbreak should be used if available. Analyses do not exist for these WBDOs, so we note a potential bias in the burden estimate.
[5] Another reason for not including averting behavior costs is because the COI approach typically does not include these types of costs (U.S. EPA, 2005). In addition, we could not determine the duration of each outbreak (not the duration of illness) or when and for how long individuals changed their behavior. Therefore, given these uncertainties, we decided not to evaluate the averting behavior costs.

only two of the reported gastrointestinal disorders: foodborne and chronic diarrhea. Ezzati-Rice et al. (2004) presented the costs of health care based on the Medical Expenditure Panel Survey; we included their per person expenditures for hospital visits and ER visits. All cost estimates are adjusted to 2000$ using the consumer price index (CPI) for medical care. Our analysis could have utilized U.S. EPA's expanded analysis of Corso et al. (2003); however, for simplification purposes and to utilize the duration of illness estimates from the WBDOSS, we decided to proceed with the approach in Corso et al.

4.1.1. Severity Classification. In this analysis, physician visits, emergency room visits, hospitalizations and deaths are surrogate measures for the severity of illness in reported WBDOs (Table 4-2). We use the same measures of severity that Corso et al. (2003) used in their Milwaukee WBDO analysis. Because the WBDOs reported in the surveillance system do not identify cases of illness by severity categories of mild, moderate and severe, this introduces additional uncertainty into the COI estimates.

TABLE 4-2

Illness Severity Definitions

Category	Definition
Severe Illness	Hospitalizations + Deaths*
Moderate Illness	Physician Visits + ER Visits
Mild Illness	All reported cases that are not moderate or severe

* Although we do not estimate a monetary burden for premature mortality, we make the assumption that all individuals who died prematurely were hospitalized. Therefore, the morbidity effects should be quantified.

The unit of reporting in the WBDOSS is an outbreak; therefore, it is not possible to match severity measures at the individual case level or distinguish whether there is an overlap in reported physician visits, emergency room visits, hospitalizations and deaths. For example, some individuals who visit a physician or emergency room may also require hospitalization. Thus, in some outbreaks, using the severity definitions in Table 4-2, there is a slight overestimation of severe illnesses. Since the numbers of

physician visits, emergency room visits, hospitalizations and deaths are relatively small compared to the total number of cases, this slight overestimation likely has minimal impact on the COI analysis (see sensitivity analysis in Chapter 6). In addition, the number of mild, moderate or severe cases does not exceed the total number of cases reported for any outbreak.

Table 4-3 shows the distribution of reported cases in reported WBDOs by the three severity categories. The distribution of protozoan illnesses in WBDOs by severity categories was similar to the distribution reported by Corso et al. in the Milwaukee *Cryptosporidium* outbreak. The distribution of mild, moderate and severe cases of viral WBDOs and all WBDOs in reported outbreaks was fairly similar to the cases of protozoan WBDOs. This provides some support to using the Milwaukee data for the COI analysis. The distribution of acute gastrointestinal illness (AGI) shows a greater percentage of moderate cases than the other groups. The reported bacterial WBDOs have a greater percentage of severe cases than the other etiologic groups (Table 4-3). Thus, we probably underestimated the burden for bacterial and AGI WBDOs based on this COI approach.

4.1.2. Costs of Self-Medication (SM). For an outbreak, the cost of SM is the total cost of over-the-counter medications for mild, moderate and severe illness (e.g., anti-nausea, anti-diarrheal medications and electrolyte replacement therapy). Corso et al. (2003) obtained information from medical charts about the percentage of moderately and severely ill individuals who self-medicated prior to seeking healthcare during the Milwaukee outbreak. Corso et al. assumed that the percentage of mild cases (30%) that self-medicated was similar to that for moderate cases of illness. The SM cost for mild illness prior to seeking healthcare was an assumption made by Corso et al.

In the COI analysis, we use the percentage of cases that self-medicate and the estimated SM costs reported in Corso et al. (Table 4-4). We calculate the SM cost by multiplying the number of illnesses in each severity category by the corresponding SM cost and the percent that self-medicated. The total SM cost for a WBDO is the sum of self-medication costs for mild, moderate and severe cases. These calculations are based on an assumption that the distribution of persons who self-medicate and the SM costs incurred during the Milwaukee *Cryptosporidium* outbreak are similar to the distribution of persons who self-medicate and the SM costs incurred during WBDOs caused by other etiologies.

TABLE 4-3

Distribution of Cases Using Estimated Severity Measures for Monetary Burden

Severity Classification	AGI		Viruses		Bacteria		Protozoa		All WBDOs	
	Cases	Percent	Cases	Percent	Cases	Percent	Cases	Percent	Cases	Percent
Mild	65,048	78	13,634	87	17,718	85	402,318	89	498,718	88
Moderate	18,066	22	2,032	13	2,125	10	43,040	10	65,263	11
Severe	379	0	92	1	943	5	4,567	1	5,981	1
Total	83,493	100	15,758	101*	20,786	100	449,925	100	569,962	100

* Rounding error, column does not total to 100

TABLE 4-4

Estimated Cost of Self-Medication*

Item	Mild	Moderate	Severe	Notes
% Self-Medication	30%	30%	29%	Corso et al. (2003)
Cost of Self-Medication (1993$)	$5.73	$5.92	$6.74	Corso et al. (2003)
Cost of Self-Medication (2000$)	$7.40	$7.65	$8.79	

* $SM = N_{mild} \times \$7.40 \times 0.3 + N_{mod} \times \$7.65 \times 0.3 + N_{sev} \times \$8.79 \times 0.29$
where:

N_{mild} = Number of mild cases
N_{mod} = Number of moderate cases
N_{sev} = Number of severe cases

4.1.3. Cost Associated with Physician Visit (PV). The costs associated with a physician visit include the professional fee and any prescribed medication (not SM cost).[6] Our PV analysis is based on the Corso et al. (2003) economic analysis of the 1993 Milwaukee *Cryptosporidium* outbreak. We assumed that the cost of a PV is similar for cases in WBDOs of *Cryptosporidium* and other etiologies. Cost estimates of PV are updated to 2000 dollars using the CPI for medical care (Table 4-5). Information about physician visits is not requested on the WBDO report form (CDC 52.12) but is reported for 4% of the reported WBDOs.

TABLE 4-5

Estimated Cost of Physician Visits*

Item	Cost	Notes
Cost of Physician Visit (1993$)	$45.00	Corso et al. (2003)
% Prescribed Medication	54%	Corso et al. (2003) Moderate Illness
Cost of Prescribed Medication	$8.91	Corso et al. (2003) Moderate Illness
Estimated Cost of Prescribed Medication per Physician Visit	$4.81	(0.54 x $ 8.91)
Estimated Cost of Physician Visit (1993$)	$49.81	$45.00 + $4.81
Cost of Physician Visit (2000$)	$64.50	

* PV = Number of Physician Visits x $64.50

4.1.4. Cost Associated with Visiting an Emergency Room (ER). The cost of an ER visit includes the costs of the ER, attending physician, ambulance and prescribed medication. An ER visit is not considered a hospitalization. If an ER visit results in a hospital admission, then the visit is also counted as a hospitalization. Information on

[6] For the costs associated with physician visits, emergency room visits or hospitalizations, the WBDOSS does not distinguish between different healthcare utilization visits by the same individual. Therefore, our cost estimates will not capture this.

ER visits is not requested on the WBDO report form (CDC 52.12) and is only reported in 2% of the outbreaks. Thus, the number of ER visits is likely under-reported in the WBDOSS, and the corresponding costs associated with these cases as reported also would be underestimated. Estimated ER visit costs are based on Corso et al. (2003). We assumed that the costs of a visit, ambulance and prescribed medicine and the percentage of cases requiring an ambulance (16%) and medication (48%) are similar for WBDOs of *Cryptosporidium* and other etiologies. The ER cost estimate is updated to 2000 dollars using the CPI for medical care (Table 4-6).

TABLE 4-6

Estimated Cost of Emergency Room Visits*

Item	Cost	Notes
Cost of Emergency Room Visit (1993$)	$224.00	Corso et al. (2003)
Percent Requiring Ambulance	16%	Corso et al. (2003) Severe Illness
Cost of Ambulance (1993$)	$228.00	Corso et al. (2003) Severe Illness
Estimated Cost of Ambulance per Emergency Room Visit (1993$)	$37.16	(0.16 x $228.00)
Percent Requiring Prescription Medication	48%	Corso et al. (2003) Severe Illness
Cost of Prescription Medication (1993$)	$70.52	Corso et al. (2003) Severe Illness
Estimated Cost of Prescription Medication per Emergency Room Visit (1993$)	$33.85	(0.48 x $ 70.52)
Total Estimated Emergency Room Visit Cost per Emergency Room Visit (1993$)	$295.01	$224.00 + $37.16 + $33.85
Total Estimated Emergency Room Visit Cost per Emergency Room Visit (2000$)	$382.02	

*ER = Number of ER Visits x $382.02

4.1.5. Cost Associated with Hospital Stay (H). Hospitalization costs are based on the 1997 Nationwide Inpatient Sample data by Health Care Utilization Project (HCUP, 1997). The Nationwide Inpatient Sample is a statistically valid sample of hospital discharges, diagnoses and charges for over 7 million hospital stays in the United States in 1997. Individual discharges were selected based on the occurrence of specific ICD-9 codes among the first three diagnoses listed on the hospital discharge report. Observations were analyzed for specific pathogens and groups of pathogens, and the HCUP reported the total hospitalization charges for selected pathogens or categories. Since total hospital charges were developed for specific etiologies and included the natural range of symptom severities for selected pathogens, all stages of disease severity should be captured.

For the COI analysis, we considered the number of reported and estimated hospitalizations for each WBDO and the average charge per hospitalization (Table 4-7). When estimates were not available or not reported for a specific pathogen, appropriate pathogens were grouped. For AGI outbreaks, we used hospitalization charges from "Diarrhea and Gastroenteritis, Undetermined Agent," ICD codes 001-009 (excluding 3.2 and 6.2), 558.9 and 787.91.

Using the CPI for medical care, we updated HCUP information for hospitalization charges in 1997 dollars to 2000 dollars. Next, we multiplied the hospital charges by the national case-weighted cost-to-charge ratio of 0.61 (Friedman et al., 2002).[7]

4.1.6. Cost Due to Loss in Productivity. Productivity losses can arise from decreased production at work and decreased household production due to illness, and we considered productivity losses for two groups:

- Ill person who recovers (PI)
- Caregiver(s) for ill person (PCG)

Productivity losses can potentially have two components: complete days lost and presenteeism (i.e., lost productivity while working). We only calculate the value of a complete day lost (see Figure 4-1). Therefore, we assume that individuals, once they return to work, do not have reduced hours and are working at full capacity even though the illness is still occurring (i.e., Table 4-8 shows the difference between days lost

[7] One aspect of hospitalization costs not included in our analysis is the additional costs for specialty physicians (billed separately). Finkelstein et al. (2006) estimate hospitalization costs to increase by a factor of 1.26 when examining the economic burden of injuries.

TABLE 4-7

Estimated Charges per Hospitalized Case*

Disease or Etiologic Agent	ICD Codes	Mean Charge (2000$)
Bacterial Infections	Calculated	$7,836.34
Yersinia	8.44	$9,677.97
Typhoid	002	$16,172.96
Shigellosis	004	$6,781.94
Other *Salmonella* Infections	003 (excluding 3.2)	$9,825.80
E. coli O157:H7 & other	8.0	$8,605.38
Cholera	001	$5,752.38
Campylobacter	8.43	$8,027.91
Other Virus Unspecified	088	$4,351.20
Norovirus	8.63	$4,518.06
Rotavirus	8.61	$3,919.09
Calicivirus	8.65	$1,885.95
Adenovirus	8.62	$11,538.71
Protozoan Infections	Calculated	$9,093.80
Cryptosporidium	7.4	$13,886.10
Giardia	7.1	$7,257.03
Diarrhea and Gastroenteritis, Undetermined Agent	001-009 (excluding 3.2 and 6.2), 558.9, 787.91	$7,603.87

* H = Number of Hospitalizations x Hospitalization Charge for Specific Pathogen or Pathogen Group x 0.61

TABLE 4-8

Productivity Losses by Severity for Ill Persons and Caregivers for Waterborne Outbreaks

Category	Mild	Moderate	Severe
Mean Days Lost for Work, Ill Persons (Corso et al., 2003)	1.3	3.8	13.5
Mean Days Lost for Work, Caregivers (Corso et al., 2003)	0.1	1.3	3.9
Mean Days Lost for Work, Ill Persons / **Median Duration** of Outbreak*	14.4%	42.2%	150.0%
Mean Days Lost for Works, Caregivers / **Median Duration** of Outbreak*	1.1%	14.4%	43.3%

* The rates of productivity loss shown are for a WBDO with a median duration of 9 days.

from work by severity). This differs from the approach used in U.S. EPA (2006a), which based results on Harrington et al. (1991). Harrington and colleagues report that employees worked at approximately a 30% capacity once they returned to work. We decided not to estimate the lost productivity while working because our calculation for complete days lost does not easily provide an estimate of lost productivity days by severity classification. This suggests that we are underestimating productivity losses.

Grosse (2003) estimated average earnings for each age and gender group in which earnings were comprised of two broad components: wages/fringe benefits and household production. The wage components included salary income, overtime pay, bonus pay and self-employment earnings based on the Current Population Survey (CPS, 2001). Fringe benefits included health insurance and retirement pay. Household production included a number of valued activities, such as cleaning, cooking, home and auto maintenance, child care and child guidance, for which individuals are typically not compensated. Grosse assumed that the average person works 250 days per year and that household services need to be performed every day. Combining the data for men and women, Grosse (2003) estimated the value of a lost day of primary activity to be $144/day (2000$)[8,9] using the following formula:

Value of a lost day = (Annual Earnings/250) + (Annual Household Services/365) (Eq. 4-2)

We used this estimate in all calculations of PI and PCG.[10]

4.1.6.1. Productivity Losses for Ill and Caregiver (PI, PCG) — For persons who are ill and recover, we estimated time lost from work for both ill persons and their caregivers (Table 4-8). We based the distribution of productivity losses on the analyses by Corso et al. (2003). Corso et al. categorized cryptosporidiosis cases into three groups based on information gathered during a random phone survey done by the City

[8] Harrington et al. (1991) estimated productivity losses at $42.82/day (2000$), which is more than $100 lower than our estimate. We attribute this partially to their lengthy average duration (41.6 days), in which they estimated a mean productivity loss of $730 (1984$). They suggest that their duration appears extraordinarily long compared to other *Giardia* outbreaks. Mean productivity loss was calculated by adding value of workdays lost and loss of productivity. This mean loss is $17.55/day (1984$) of illness.
[9] This value was derived from a 2000 data source, so it was not inflated using a CPI measure.
[10] The difference between U.S. EPA's traditional and enhanced COI for this particular calculation is the value of lost unpaid work time for the traditional COI, which is half the value of the enhanced COI. Other approaches to estimate the value of a day lost are available (e.g., see U.S. EPA, 2006a), which calculates the value of a lost work day as a fraction of a full day, 3.5 hours). When combining both lost work time and lost unpaid work time, the estimate of $144 is still $67 and $55 higher than U.S. EPA (2006a) traditional and enhanced COI, respectively.

of Milwaukee Health Department. Categorization into mild, moderate or severe depended on the type of medical care received and days of productivity lost for the ill and their caregivers. Due to limited reported data, Corso et al. estimated the days of productivity lost for caregivers with severe illness cases assuming that caregivers were needed for 50% of the duration of hospitalization for the ill person. Productivity losses for the ill and their caregivers were determined for the other WBDOs by multiplying the rates for each illness severity by the reported or estimated median duration for each WBDO (Table 4-8). For these other non-Milwaukee WBDOs, we used information from the WBDOSS to obtain actual or estimated values for the median duration for the various etiologic agents.

For each outbreak, we calculated cost due to complete days lost of productivity for both the ill person and caregiver by the following equations:

$$PI = [(N_{mild} \times R_{mild}) + (N_{mod} \times R_{mod}) + (N_{sev} \times R_{sev})] \times D \times L_D \quad \text{(Eq. 4-3)}$$

$$PCG = [(N_{mild} \times R_{mild}) + (N_{mod} \times R_{mod}) + (N_{sev} \times R_{sev})] \times D \times L_D \quad \text{(Eq. 4-4)}$$

where:

N = Number of cases
D = Median duration of illness
R = Rate of days lost for work based on illness duration (Table 4-8)
L_D = Value of a lost day = $144/day (2000$).

To compute the lost productivity costs from Table 4-8, we assumed

- productivity losses are always some constant fraction of the duration of illness based upon severity grouping
- other waterborne pathogens have a similar rate of productivity loss to median duration of illness as *Cryptosporidium.*

We are uncertain how representative these rates are for assessing the severity of other pathogens. Additional studies are needed to test the validity of these assumptions.

4.2. ESTIMATING THE MONETARY BURDEN OF THE WATERBORNE OUTBREAKS

The monetary burden (2000$) presented in Table 4-9 is based on the methodology described in Section 4.1 and the epidemiologic burden measures developed in Chapters 2 and 3 for the WBDOs that occurred from 1971 to 2000. It is important to note that the monetary burden quantified in this section describes only a subset of the total monetary burden associated with waterborne outbreaks. Using a COI approach, we calculate the burden of the morbidities associated with the WBDOs to be approximately $202 million. The largest cost of morbidity is lost productivity of the ill person (61% of COI) while hospitalization costs and lost productivity of the caregiver follow in relative impact (23% and 10% of total COI, respectively). Following the approach described in this chapter, Chapter 5 presents comparisons of the monetary burden by different summary categories.

TABLE 4-9

Projected Monetary Burden of Infectious Waterborne Outbreaks in Drinking Water, 1971 to 2000

Burden Measure	Monetary Burden* (2000$)	Percent of Total Monetary Burden
Self-Medication	$1,272,000	1
Physician Visits	$2,708,000	1
Emergency Room Visits	$9,006,000	4
Hospitalizations	$45,652,000	23
Ill Productivity Losses	$123,357,000	61
Caregiver Productivity Losses	$19,721,000	10
Total	$201,716,000	100

* The estimate of monetary burden does not include presenteeism, lost leisure time, pain and suffering, defensive expenditures, investigation or litigation costs, or chronic illness costs (see Figure 4-1).

5. RESULTS: MONETARY BURDEN ESTIMATE OF OUTBREAKS BY SUMMARY CATEGORIES AND IMPACT OF THE MILWAUKEE OUTBREAK

This chapter describes the differences in the monetary burden by etiology, water system type, water system deficiency and water source type. It is important to note that the monetary burden quantified in this chapter describes only a subset of the total monetary burden associated with waterborne outbreaks. To compare the monetary burden among different pathogens and be consistent with the epidemiologic analyses in Chapter 3, we evaluated the etiologies by water source type and treatment deficiency. Because the Milwaukee outbreak has a large effect on the epidemiologic burden measures, we anticipated that it would affect the overall summary and category-specific monetary burdens. Thus, we also considered the effects of the Milwaukee outbreak on the monetary burden.

As stated in Chapters 1 and 4, we did not estimate the monetary burden of the deaths associated with the outbreaks. In our analyses, we examined the number of reported deaths (see Chapter 3) and conducted a sensitivity analysis to estimate a plausible range of deaths that might be attributable to waterborne outbreaks (see Chapter 6). The monetary measures reported in this chapter are based on the COI approach described in Chapter 4 and are adjusted to 2000$ using the CPI for medical care; the approach estimated:

- Costs of medical care
- Costs of prescribed medication and self-medication
- Productivity losses at work and home.

5.1. MONETARY BURDEN BY ETIOLOGY

The total burden attributed to reported waterborne outbreaks in the WBDOSS from 1971-2000 was $202 million (Table 5-1). Since protozoan agents accounted for the most cases of the person-days ill, physician visits, emergency room visits, hospitalizations and deaths (Table 3-2), they are responsible for 85% of the monetary burden (Table 5-1). Bacterial and viral outbreaks contribute only 5% and 2% of the monetary burden, respectively. Waterborne outbreaks of undetermined etiology (AGI) contribute 8% of the monetary burden, which was expected because AGI WBDOs were associated with the second highest epidemiologic burden for several measures including person-days ill, physician visits and emergency room visits. Bacterial outbreaks were associated with more hospitalizations than AGI outbreaks (Table 3-2).

TABLE 5-1

Monetary Burden of Infectious Waterborne Outbreaks in Drinking Water, 1971 to 2000, by Etiology (Pathogen Group)

Pathogen Group	Outbreaks	Monetary Burden[a]
AGI	365	$15,711,000
Viruses	56	$3,336,000
Bacteria	101	$10,727,000
Protozoa	143	$171,942,000[b]
Total	665	$201,716,000

[a] All estimates in 2000$.
[b] Monetary Burden of Milwaukee outbreak, $152,479,000, is 89% of the monetary burden associated with protozoa.

If the Milwaukee outbreak is excluded from our analysis, AGI and protozoan outbreaks accounted for similar proportions of the total monetary burden. Protozoan outbreaks would contribute 39%[1] of the monetary burden while AGI outbreaks would contribute 32%; bacterial and viral outbreaks would contribute 22% and 7%, respectively.

Cryptosporidium is the major contributor to the monetary burden for all WBDOs and protozoan outbreaks (Table 5-2). It was responsible for 78% of the burden for all waterborne outbreaks and 91% of the burden for protozoan outbreaks. *Giardia* contributed 8% of the monetary burden for protozoan outbreaks; the other protozoan agents (i.e., *Cyclospora* and *En. histolytica*) contribute minimally to the monetary burden estimate. However, if we excluded the Milwaukee outbreak from the analysis, *Giardia* would then contribute 71% of the monetary burden associated with protozoan outbreaks with *Cryptosporidium* contributing only 29%.

Non-typhoid *Salmonella* spp. and *E. coli* are the major contributors to the monetary burden of bacterial WBDOs (Table 5-2). Hepatitis A is the major contributor to the monetary burden of viral outbreaks, almost double that of the norovirus outbreaks, the second largest contributor to viral outbreak burden (Table 5-2).

5.2. MONETARY BURDEN BY WATER SYSTEM TYPE

Water systems are classified as community, non-community or individual as defined in Chapter 1 and Appendix A. Community water systems had the largest monetary disease burden between 1971 and 2000 (Table 5-3)—nine times larger than the monetary burden associated with non-community water systems and nearly 90 times larger than the monetary burden associated with individual water systems.

We estimated the monetary burden for the outbreak that occurred in Milwaukee, which is a community water system, to be $152,479,000. If we excluded the Milwaukee outbreak from the analysis, community water systems accounted for the largest contribution to the monetary burden (56%). Non-community and individual water systems accounted for 40% and 4%, respectively. The proportion of the monetary burden attributable to non-community systems was influenced by the large number of hospitalizations and emergency room visits.

5.3. MONETARY BURDEN BY WATER SYSTEM DEFICIENCY

When the analysis was stratified by the type of water system deficiencies, the most important contributor to the monetary burden was having one or more deficiencies

[1] Throughout this chapter, percentages listed in text may differ slightly from those that could be calculated from tables due to rounding in the tables.

TABLE 5-2

Monetary Burden of Infectious Waterborne Outbreaks in Drinking Water, 1971 to 2000, by Etiology (Specific Pathogens)

Etiologic Agent	Outbreaks	Monetary Burden
AGI		
AGI	365	$15,711,000
Viruses		
Hepatitis A	28	$2,212,000
Norovirus	26	$840,000
Rotavirus	1	$282,000
SRSV (assumed to be norovirus)	1	$3,000
Bacteria		
S. enterica serovar Typhi	5	$3,674,000
Shigella	44	$2,822,000
C. jejuni	19	$1,245,000
E. coli O157:H7 & other	12	$1,091,000
Salmonella, non-typhoid spp.	15	$1,090,000
E. coli O157:H7 *& Campylobacter*	1	$566,000
Yersinia	2	$191,000
P. shigelloides	1	$24,000
V. cholerae	2	$23,000
Protozoa		
Cryptosporidium	15	$158,130,000*
Giardia	126	$13,795,000
En. histolytica	1	$11,000
Cyclospora	1	$6,000
Total	665	$201,716,000

* Monetary Burden of Milwaukee outbreak, $152,479,000, is 96% of the monetary burden associated with *Cryptosporidium.*

TABLE 5-3

Monetary Burden of Infectious Waterborne Outbreaks in Drinking Water, 1971 to 2000, by Water System Classification Type

Water System Classification	Outbreaks	Monetary Burden
Community	254	$180,247,000*
Non-Community	329	$19,382,000
Individual	82	$2,087,000
Total	665	$201,716,000

* Monetary Burden of Milwaukee outbreak, $152,479,000, is 84% of the monetary burden for community systems.

(e.g., inadequate or interrupted disinfection or filtration) in the treatment of drinking water (Table 5-4). Drinking water contamination caused by inadequate or interrupted water treatment was responsible for 92% of the monetary burden. The use of untreated, contaminated groundwater and contamination of the water distribution network (e.g., pipes and storage facilities maintained by the water utility and plumbing within buildings) were associated with 4% and 3% of the monetary burden, respectively. The smallest burden (<1%) was associated with outbreaks caused by miscellaneous (e.g., contaminated water taps, ice, containers), unknown deficiencies and untreated surface water. Waterborne outbreaks caused by the use of untreated surface water occurred early in the reporting period; most of these public water systems are now filtered (U.S. EPA, 2006a).

The Milwaukee outbreak was attributed to inadequate water treatment. If the Milwaukee outbreak is excluded from the analysis, water treatment deficiencies are still the most important contributor to the monetary burden (66%); untreated groundwater and distribution system contamination contributed 16% and 12% respectively.

Similar to the person-days ill and mortality analyses in Chapter 3, we evaluated the monetary burden associated with each etiologic agent for the important water system deficiencies (Figures 5-1 to 5-4) and water sources (Figures 5-5 to 5-6).

Cryptosporidium outbreaks accounted for most (85%) of the monetary burden associated with water treatment deficiencies (Figure 5-1a). *Giardia* and AGI outbreaks caused by inadequate water treatment are associated with nearly all (11%) of the remaining monetary burden (15%). The Milwaukee *Cryptosporidium* outbreak was associated with 82% of the monetary burden attributable to outbreaks caused by inadequate water treatment. If the Milwaukee outbreak is excluded from the analysis, most (65%) of the monetary burden associated with inadequate water treatment would be from *Giardia* and AGI outbreaks (Figure 5-1b).

Giardia (44%) and AGI (22%) account for most (65%)[2] of the monetary disease burden attributed to water distribution system deficiencies (Figure 5-2). *Giardia* accounted for most of the person-days ill in these outbreaks (see Table 3-2 for more information). *S. enterica* serovar Typhi and non-typhoid *Salmonella* outbreaks contributed 21% of the monetary burden for water distribution system deficiency. *E. coli* outbreaks contributed 5% of the monetary burden for this type of deficiency.
The AGI outbreaks account for 43% of the monetary disease burden associated with the use of untreated groundwater (Figure 5-3). Hepatitis A outbreaks and *Shigella*

[2] Difference between summed individual percentages and total is due to rounding.

TABLE 5-4

Monetary Burden by Water System Deficiency Reported to the WBDOSS Between 1971 to 2000

Deficiency	Outbreaks	Monetary Burden
Deficiency in Water Treatment	269	$185,104,000[a]
Untreated Groundwater	211	$8,052,000
Distribution System Deficiency	83	$5,862,000
Unknown Deficiency	23	$1,382,000
Miscellaneous	41	$842,000
Untreated Surface Water	38	$476,000
Total	665	$201,716,000[b]

[a] Monetary Burden of Milwaukee outbreak, $152,479,000, is 82% of the monetary burden for water treatment deficiencies.
[b] Burden estimates do not sum to total due to rounding.

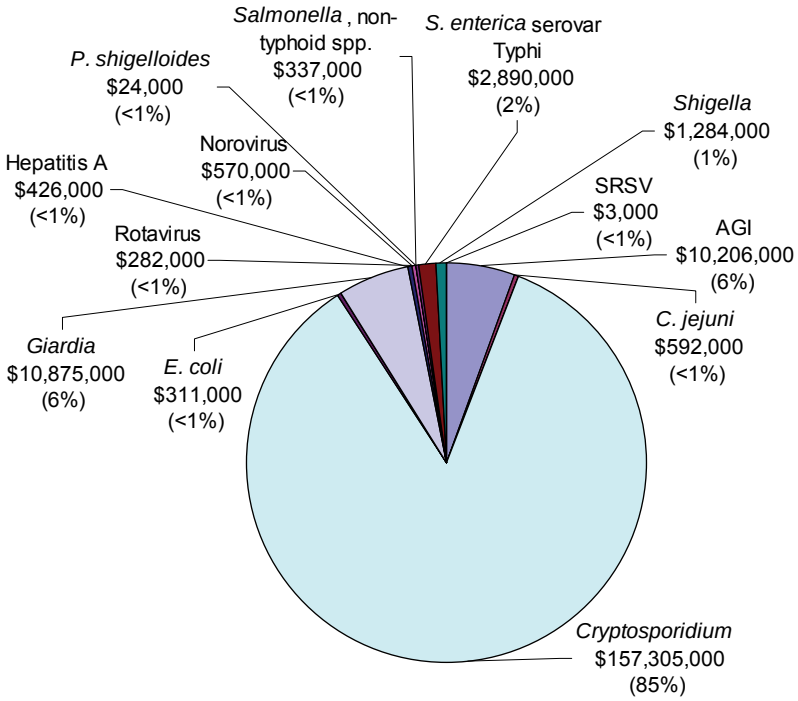


FIGURE 5-1a

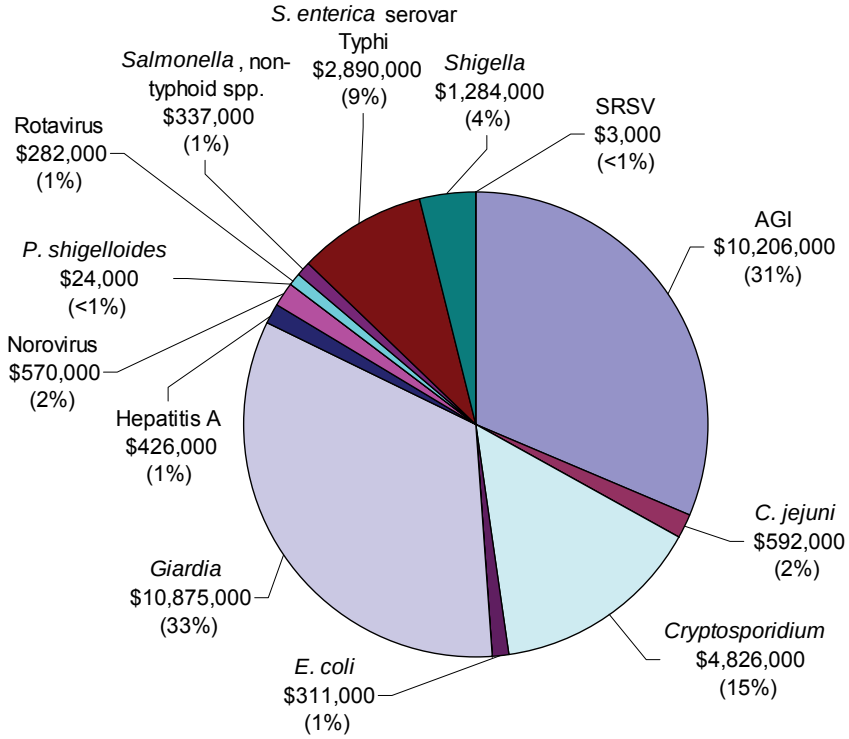


FIGURE 5-1b

Monetary Burden for Waterborne Outbreaks Attributed to Deficiencies in Water Treatment by Etiologic Agent (Figure 5-1a includes the Milwaukee Outbreak and Figure 5-1b excludes the Milwaukee Outbreak)

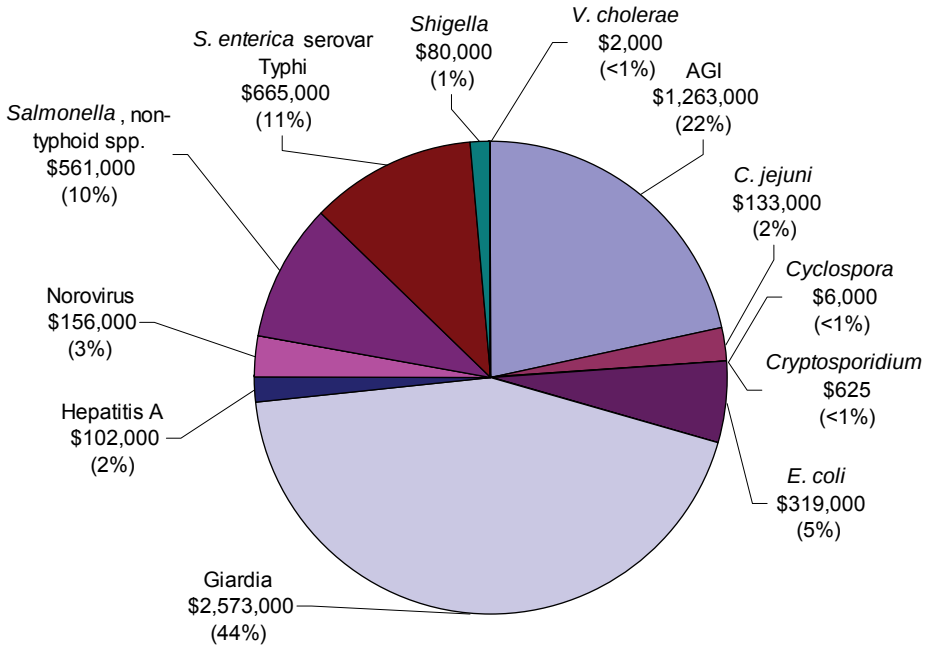


FIGURE 5-2

Monetary Burden for Waterborne Outbreaks Attributed to Distribution System Deficiencies by Etiologic Agent

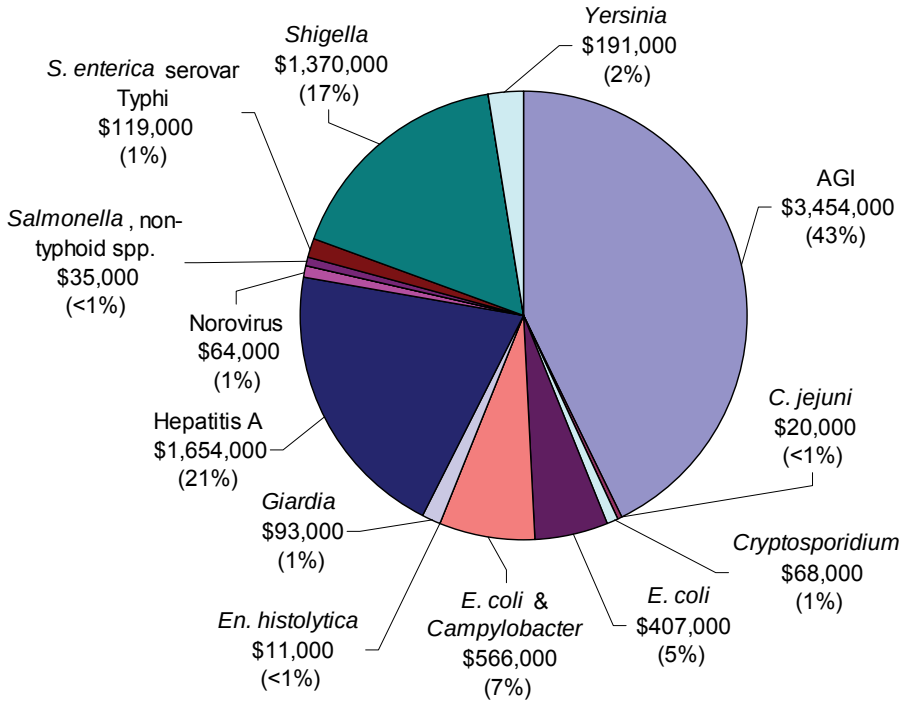


FIGURE 5-3

Monetary Burden for Waterborne Outbreaks Attributed to Untreated Groundwater by Etiologic Agent

outbreaks are associated with 21 and 17% of the total untreated groundwater monetary burden, respectively. AGI and hepatitis A caused the most person-days ill in untreated groundwater outbreaks.

The monetary burden associated with the remaining water system deficiencies is substantially smaller than the monetary burden associated with water treatment deficiencies, distribution system contamination and use of untreated groundwater. We evaluate the monetary burden associated with the use of untreated surface water, although this deficiency is no longer important in the U.S. because treatment is now mandated in such systems (U.S. EPA, 2006). When the cause of the outbreak was attributed to untreated surface water, *Giardia* (47%) and AGI (37%) outbreaks accounted for most of the monetary burden (Figure 5-4); the same etiologic agents also accounted for most of the person-days ill associated with untreated surface waters.

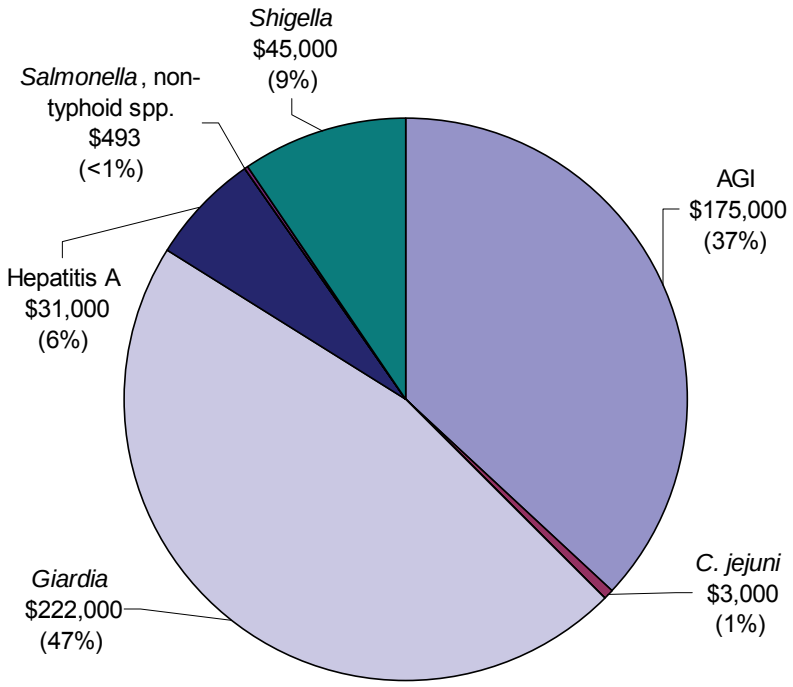


FIGURE 5-4

Monetary Burden for Waterborne Outbreaks Attributed to Untreated Surface Water by Etiologic Agent

5.4. MONETARY BURDEN BY WATER SOURCE TYPE

Although fewer outbreaks were reported in surface water systems than in groundwater systems, surface water system outbreaks accounted for 85% of the total monetary burden whereas groundwater outbreaks contributed only 14% of the burden (Table 5-5). The monetary burden of the Milwaukee outbreak, alone, contributed 89% of the monetary burden for outbreaks that occurred in surface water systems. If the Milwaukee outbreak is excluded from the analysis, groundwater outbreaks accounted for 56% of the monetary burden. Surface water outbreaks accounted for slightly less than 40%, while unknown and mixed water sources are negligible contributors to the monetary burden.

TABLE 5-5

Monetary Burden by Water Source Type Reported to WBDOSS Between 1971 to 2000

Water Source	Outbreaks	Monetary Burden
Surface Water	117	$172,053,000*
Groundwater	110	$27,494,000
Unknown	23	$1,320,000
Mixed	4	$849,000
Total		$201,716,000

* Monetary Burden of the Milwaukee outbreak, $152,479,000, is 89% of the monetary burden for surface water.

Waterborne outbreaks attributed to protozoan agents are the predominate contributors to the monetary burden associated with surface water systems. *Cryptosporidium* outbreaks are associated with almost the entire monetary burden for surface water system outbreaks. If the Milwaukee outbreak is excluded, the impact of *Cryptosporidium* outbreaks would be greatly reduced (Figure 5-5b). Excluding the Milwaukee outbreak, *Giardia* and AGI outbreaks would contribute most of the monetary burden. Outbreaks attributed to bacterial agents are the predominate contributors to the monetary burden associated with groundwater system outbreaks. Because of the importance of water system deficiencies that may be associated with source waters, we evaluated these in more detail (Figures 5-5a, 5-5b, 5-6). Outbreaks that were reported in water systems

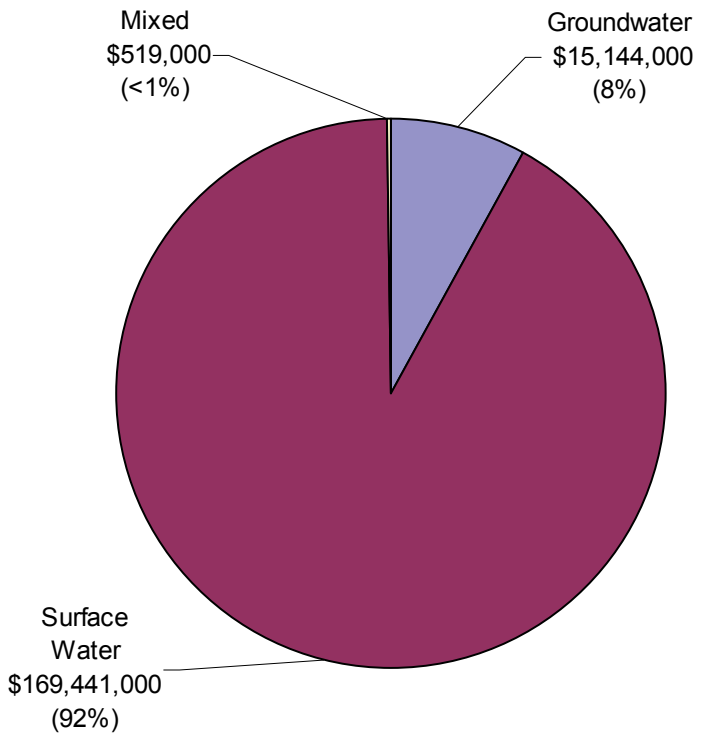


FIGURE 5-5a

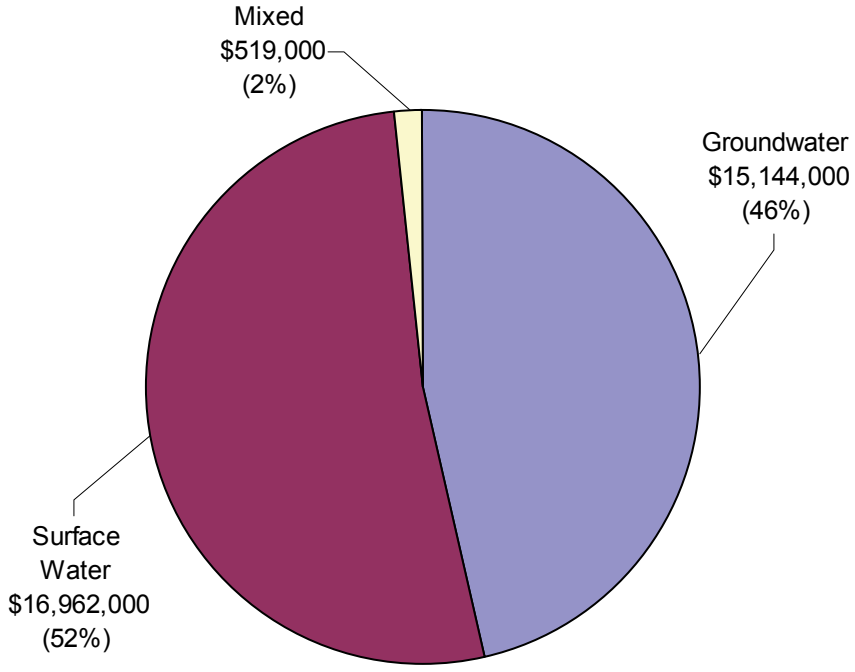


FIGURE 5-5b

Distribution of Monetary Burden of Waterborne Outbreaks Attributed to Water Treatment Deficiency by Source Water Type (Figure 5-5a includes the Milwaukee Outbreak and Figure 5-5b excludes the Milwaukee Outbreak)

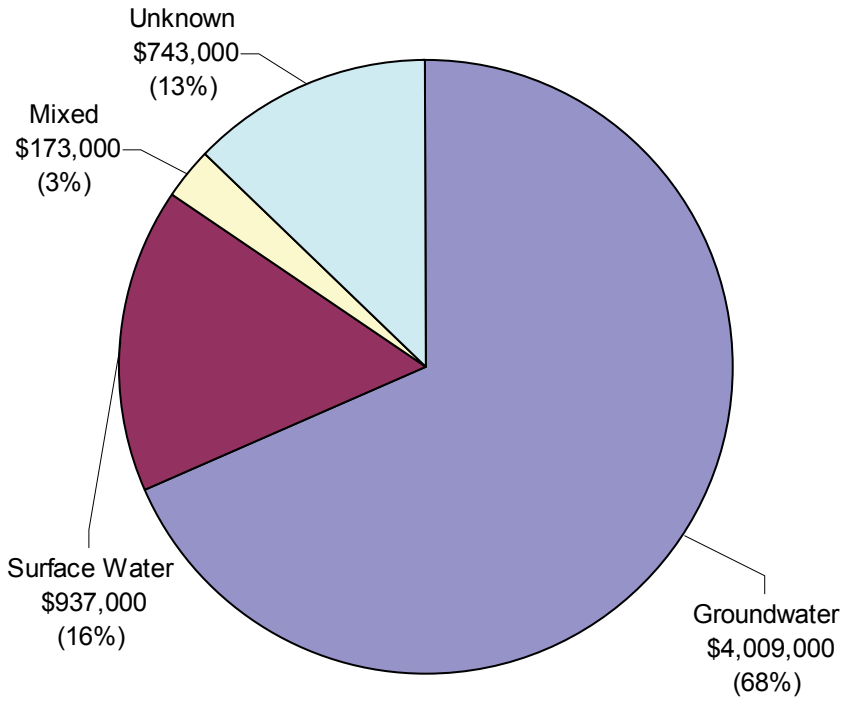


FIGURE 5-6

Distribution of Monetary Burden of Waterborne Outbreaks Attributed to Distribution System Deficiency by Source Water Type

using surface water sources are associated with almost all (92%) of the monetary burden (Figure 5-5a), but this contribution becomes slightly greater than the monetary burden associated with outbreaks that occurred in groundwater systems if the Milwaukee outbreak is excluded (Figure 5-5b). When we evaluated outbreaks that were caused by distribution system deficiencies, most (68%) of the monetary burden was associated with outbreaks in groundwater systems, while only 16% of the monetary burden was associated with outbreaks in distribution systems that used surface water (Figure 5-6).

5.5. THE IMPACT OF THE MILWAUKEE CRYPTOSPORIDIOSIS OUTBREAK ON COMPONENTS OF OVERALL MONETARY BURDEN

Approximately 76% of the overall monetary burden is associated with the Milwaukee outbreak. This is largely due to lost productivity associated with ill persons; most of the person-days ill associated with the reported waterborne outbreaks in the 30-year period between 1971 and 2000 occurred during this single outbreak. Table 5-6 illustrates the influence of the Milwaukee outbreak on the monetary burden for all outbreaks by comparing the components of the monetary burden with and without the Milwaukee outbreak. The Milwaukee outbreak exclusion decreased the importance of the contributions of caregiver productivity losses, physician and ER visits and increased the importance of productivity losses and hospitalizations in the overall monetary estimate.

5.6. DISCUSSION AND CONCLUSIONS

Analysis of the monetary burden allows for a number of comparisons not easily accomplished with traditionally reported epidemiologic measures from waterborne outbreaks. Specifically, monetary metrics can be used to integrate across a number of epidemiologic endpoints facilitating comparisons that rely on the dollar metric. The monetary values presented in this chapter are based on COI approaches, which likely capture only a subset of disease attributes that individuals' value (see Chapter 4 for further information).[3] Therefore, the monetary values used for measures of morbidity likely underestimate individuals' willingness to pay to reduce the risk of incurring the morbidity.

As expected, the largest monetary burden was associated with the Milwaukee *Cryptosporidium* outbreak. The monetary burden associated with this outbreak is also

[3] COI approaches capture the costs from a societal perspective rather than an individual perspective, which is reflected in WTP measures.

TABLE 5-6

Monetary Burden of Infectious Waterborne Outbreaks in Drinking Water, 1971 to 2000 by Cost-of-Illness Measure

Burden Measure	Monetary Burden (Percent of total monetary burden in parentheses)	Monetary Burden Excluding Milwaukee (Percent of total monetary burden without the Milwaukee outbreak in parentheses)
Self-Medication	$1,272,000 (1%)	$374,000 (1%)
Physician Visits	$2,708,000 (1%)	$1,400,000 (3%)
Emergency Room Visits	$9,006,000 (4%)	$4,526,000 (9%)
Hospitalizations	$45,652,000 (23%)	$8,382,000 (17%)
Productivity Losses in Ill	$123,357,000 (61%)	$28,597,000 (58%)
Caregiver Productivity Losses	$19,721,000 (10%)	$5,959,000 (12%)
Total	$201,716,000	$49,238,000

evident when comparing the relative importance of the burden among various categories (i.e., community water systems, protozoan agents, *Cryptosporidium*, water treatment deficiencies and surface water outbreaks). These analyses demonstrated that a very large outbreak, of even moderate illness, could have a significant impact on monetary burden analyses and this conclusion is similar to that reached using the individual epidemiologic measures.

As discussed in Chapter 4, the actual number of deaths caused by waterborne outbreaks is not easily translated into monetary burden. Therefore, when looking at the tables found in Chapter 5, we suggest also considering the number of deaths from Chapter 3. For example, Table 5-4 shows that the monetary burden associated with outbreaks that were attributed to untreated groundwater was $8 million, while the monetary burden associated with outbreaks that were attributed to distribution system deficiencies was approximately $6 million; the difference between these two burden estimates is $2.19 million. When considering the number of deaths (Table 3-5), we see that outbreaks attributed to distribution system deficiencies caused 12 deaths while those attributed to untreated groundwater caused 2 deaths.

With this information, a reader may infer that the 12 deaths and approximately $6 million in monetary burden are worse than the burden and number of deaths for untreated groundwater. If so, the reader either explicitly or implicitly (through conversion to a single monetary metric) believes that each actual death is associated with least $219,000 in monetary burden (i.e., the dividend of $2.19 million and 10 incremental deaths). Without an approach for estimating the burden from mortality, the reader will implicitly value the deaths from their decision about the most burdensome deficiency. Our suggestion, therefore, is to examine both the number of deaths and monetary burden for morbidity when considering the impact from waterborne outbreaks. This underscores the need for developing methods that can be used to estimate the monetary value associated with deaths that have occurred.

As a caution and as discussed in Chapter 1, outbreak reporting is voluntary. Consequently, the surveillance data may reflect the available resources for the investigation of outbreaks and laboratory capabilities for identifying the etiologies. Thus, the monetary burden differences for a specific etiology or water system type may reflect reporting differences (see section on WBDO surveillance system limitations in Chapter 1 and Appendix A).

6. SENSITIVITY ANALYSES FOR MONETARY BURDEN

Sensitivity analyses allow for the examination of the influence of model input parameters on predictions. Allowing the values of the input parameters to vary over a range (e.g., a distribution of uncertainty in the model parameters), we can observe the relative change in model response. We conducted four such analyses to evaluate key assumptions used to develop the epidemiologic or monetary burden estimates.

In the first sensitivity analysis (Section 6.1), we identify the epidemiologic variables that had the greatest impact on the total monetary burden estimate by calculating the percent change needed in the epidemiologic estimate to change the monetary burden estimate by 5%. In the second analysis (Section 6.2), we evaluate uncertainties associated with the number of deaths attributed to waterborne outbreaks. For each pathogen, we develop plausible ranges of deaths linked to WBDOs and use a Monte Carlo approach to predict a plausible range of deaths associated with waterborne outbreaks.

The third analysis (Section 6.3) includes an examination of the impact of alternative illness durations and case estimates on the monetary burden estimated for the Milwaukee WBDO. A preliminary analysis shows that most of the variability in the distribution of person-days of illness resulted from uncertainty in the duration of cryptosporidiosis. Because the Milwaukee cryptosporidiosis outbreak is the largest outbreak reported in the WBDOSS, we focused on characterizing the impact of uncertainty regarding the duration of illness in this outbreak. About $152,479,000 of the total monetary burden estimate is associated with the Milwaukee cryptosporidiosis outbreak, 76% of the total monetary burden estimate for all WBDO.

The final analysis (Section 6.4) examines the possible impact of a chronic sequela on a burden measure. In this analysis, we identify the number of *E. coli* O157:H7 cases reported to the WBDOSS. We then develop several conditional probability estimates for the development of hemolytic uremic syndrome (HUS) following an *E. coli* O157 infection based on estimates reported in the literature. The conditional probabilities are combined with the number of cases of *E. coli* O157 infection yielding estimates of HUS. For each estimate of HUS cases, we estimate the increased cost of hospitalization.

TABLE 6-1

Reported and Projected Epidemiologic Burden Measures for U.S. WBDOs which Occurred between 1971 and 2000

Epidemiologic Burden Measure	Reported Occurrence[a]	Projected Occurrence[b]	Additional Occurrence Estimates
Person-Days Ill[c]	3,992,923	4,504,854	511,931
Hospitalizations[d]	5,915	5,915	0
Emergency Room Visits	1,013	23,575	22,562
Physician Visits	21,531	41,985	20,454

[a] Reported occurrence refers to the totals actually reported in the WBDOSS. Critical data are missing for some outbreaks (Chapter 2).
[b] Projected occurrence refers to the totals used in the main analysis (Chapters 2 and 3). These totals include estimates for data not reported to the WBDOSS (e.g., some outbreak reports show no estimate for duration of illness).
[c] Derived from the number of cases and illness duration which are requested on CDC 52.12.
[d] Requested on CDC 52.12.

6.1. SENSITIVITY OF THE MONETARY BURDEN TO THE EPIDEMIOLOGIC BURDEN MEASURES

Table 6-1 shows the epidemiologic burden measures reported for the WBDOs and their projected occurrence that were estimated in Chapter 2. It also shows the Additional Occurrence Estimates, which are the differences between the Projected and the Reported Occurrences for each measure. Because the computed rates for hospitalizations were comparable to the rates of occurrence reported in the literature, we assumed that this passive surveillance system does not underestimate significantly or miss many of these events. Consequently, we did not develop approaches to adjust the estimates for hospitalizations; Table 6-1 shows the reported and projected estimates for hospitalizations are the same. Using only the WBDOs with duration estimates would underestimate the total person-days ill associated with all reported WBDOs, because some WBDOs did not report a duration of illness. Therefore, we estimated durations for the remaining 42% of the WBDOs that did not report illness duration based primarily on the duration of illness caused by similar waterborne pathogens (see methods section in Chapter 2). We projected that there were approximately 4.5 million person-days ill associated with all of the WBDOs that were reported between 1971 and 2000; the projected estimate is roughly 500,000 person-days larger (13%) than if it had been based solely on the reported measures. Since emergency room visits and physician visits were not requested on the surveillance form, information for these visits was reported for few WBDOs; we projected additional occurrence of these measures, based primarily on reported rates for similar pathogens (Table 6-1) (see methods section in Chapter 2).

6.1.1. Method. We estimated the change in the projected occurrence of the epidemiologic burden measure needed to cause a 5% change in the total monetary burden. U.S. EPA (1997a) and Breed et al. (2004) use similar approaches in a watershed delivery model and an ecosystem productivity analysis, respectively (see also discussion of approaches to sensitivity analyses in Morgan and Henrion, 1990). As shown in Eq. 6-1, the quantity of the projected occurrence for each epidemiologic burden measure (Table 6-1) forms the denominator of the equation and the change in the projected occurrence forms the numerator. We note that the monetary value (i.e., COI estimate) weights the required change in occurrence; we hold the value constant in this analysis. Solving Eq. 6-1 for *PO* yields Eq. 6-2, which estimates the change required for each epidemiologic burden measure (converted to percentages) to change the total monetary burden by 5%.

$$TMB * 1.05 = \left(\frac{PO_C}{PO_I} \right) * V \quad \text{(Eq. 6-1)}$$

where:

TMB = Total monetary burden

PO_I = Projected occurrence for given epidemiologic burden measure used in the main analysis

PO_C = Projected occurrence for given epidemiologic burden measure needed to change TMB by 5%

V = Monetary value of given epidemiologic burden measure.

$$PO_C = \frac{TMB * 1.05 * PO_I}{V} \quad \text{(Eq. 6-2)}$$

6.1.2. Results. Table 6-2 shows that the total monetary burden was most sensitive to differences in the number of person-days ill. A 7% change in the projected number of person-days ill causes a 5% change in the total monetary burden. For hospitalizations, a 17% change is required to change the total monetary burden by 5%. For physician visits and emergency room visits, 47% and 56% are needed in the projected measures to cause a 5% change in the total monetary burden. When the Milwaukee WBDO is excluded, the total monetary burden also was most sensitive to differences in the number of person-days ill (Table 6-3); a 7% change in person-days of illness was required to change the monetary burden by 5%. For hospitalizations, a larger increase (22% vs. 17%) is required for a 5% increase in total monetary burden. In contrast, smaller changes in the measures are required to cause a 5% change in the total monetary burden for emergency room visits (34% vs. 56%), and physician visits (26% vs. 47%).

6.1.3. Discussion. The sensitivity of total monetary burden to person-days of illness is a consequence of the COI estimates for a person-day of illness and number of cases and the duration of illness. The total monetary burden was somewhat sensitive to the change in the number of hospitalizations. The projections of emergency room visits and physician visits are likely the most uncertain since no comparable epidemiologic data were identified in the published literature (Chapter 2) and the projections of these measures are based upon few WBDOs. This sensitivity analysis suggests that the total monetary burden is considerably less sensitive to these two epidemiologic measures

TABLE 6-2

Percent Change Required in the Epidemiologic Burden to Change Monetary Burden Estimate for U.S. WBDOs by 5%

Epidemiologic Burden Measure	Projected Occurrence	Change in the Projected Epidemiologic Burden Measure Required to Cause a 5% Change in the Total Monetary Burden	Percent Change in Epidemiologic Burden Measure Required to Cause a 5% Change in the Total Monetary Burden
Person-Days Ill	4,504,854	317,593	7%
Hospitalizations	5,915	1,015	17%
Physician Visits	41,985	19,752	47%
Emergency Room Visits	23,575	13,196	56%

TABLE 6-3

Sensitivity of the Monetary Burden to Changes in the Epidemiologic Burden Excluding the Milwaukee Outbreak

Epidemiologic Burden Measure	Projected Occurrence	Change in the Projected Epidemiologic Burden Measure Required to Cause a 5% Change in the Total Monetary Burden	Percent Change in Epidemiologic Burden Measure Required to Cause a 5% Change in the Total Monetary Burden
Person-Days Ill	877,854	62,548	7%
Hospitalizations	1,515	329	22%
Physician Visits	21,705	5,732	26%
Emergency Room Visits	11,848	4,002	34%

compared to person-days ill (Table 6-2). If the Milwaukee outbreak is excluded, the rank order of the measures is unchanged, but the sensitivity of the total monetary burden results to the number of emergency room visits and physician visits increases. If mortality had been valued, the burden associated with deaths likely would greatly impact the monetary burden estimates.

6.2. MONTE CARLO SENSITIVITY ANALYSIS OF THE DISTRIBUTION OF WBDO DEATHS

Although we do not estimate the monetary burden associated with premature death, it is the most severe of the epidemiologic outcomes and, if the monetary burden associated with deaths was evaluated, it likely would contribute significantly to the monetary burden estimate. In this sensitivity analysis, we developed a plausible distribution of the deaths associated with WBDOs. We used distributions of the plausible number of deaths that could be associated with WBDOs for each pathogenic agent, as ascertained by case-fatality estimates from literature sources. We used Monte Carlo methods to predict an overall distribution of the epidemiologic burden estimate. Monte Carlo approaches provide a means of incorporating the uncertainty around each input parameter, as long as the uncertainty can be described in terms of a statistical distribution. The purpose is to identify the primary sources of uncertainty in the estimate and to develop a plausible distribution of the deaths in the reported WBDOs.

Monte Carlo simulation is a mathematical technique that randomly chooses a value for each variable (within a specified probability distribution) used in a model (i.e., for each run of the Monte Carlo model, a single value for each uncertain parameter is drawn from the distributions describing the uncertain parameters). This analysis treats each input as a statistically independent parameter. Based on the chosen values, this technique calculates an output value. The selection and calculation steps are repeated multiple times. The outcomes are compiled forming a probability distribution for the output variable. This distribution is used to estimate the likelihood of a specific outcome (e.g., what is the median or 95th percentile value). Such simulations can also be used to examine which variables have the largest influence on model output (Cullen and Frey, 1999).

6.2.1. Methods.

6.2.1.1. Distributions of Deaths — For each etiologic agent category (except *Cryptosporidium*), we developed distributions of the plausible number of deaths that

could be expected if the lowest and highest case-fatality ratios from the literature sources discussed in Chapter 2 (see Table 2-10 in Section 2.9) are applied to the cases reported to the WBDOSS (Table 6-4).

The 50 reported deaths in the WBDOSS that are attributed to *Cryptosporidium* in Table 6-4 are based on the death certificate analysis of Hoxie et al. (1997) that identified cryptosporidiosis as the underlying or a contributing cause of death among residents of the Milwaukee vicinity who died during the 2-year period following the Milwaukee outbreak. The analysis revealed 54 cryptosporidiosis-associated deaths that occurred during that time interval, whereas, based on pre-outbreak trends, only four would have been expected. Hoxie and colleagues also demonstrate that the total number of AIDS deaths, excluding cryptosporidiosis-associated AIDS deaths, was significantly greater than predicted during the 6 months after the outbreak (19 more deaths than expected [95% CI=12, 26]) and that non-cryptosporidiosis-associated AIDS deaths were lower than expected during the subsequent two 6-month intervals. These changes in the pattern of AIDS deaths suggest that premature mortality among persons with AIDS could have been associated with the outbreak and that cryptosporidiosis as a contributing cause of death may have been under-reported on their death certificates.[1] Should that have been the case, the 19 excess AIDS deaths that occurred within 6 months after the outbreak may have been cryptosporidiosis-associated, and as such, will be considered in our analysis of the distribution of plausible number of deaths. Conversely, the 50 cryptosporidiosis-associated deaths attributed to the Milwaukee WBDO may be an overestimate due to increased cryptosporidiosis awareness following the outbreak, but the available data are inadequate to determine a possible lower bound for cryptosporidiosis mortality.

Application of the very high case-fatality ratios reported for *Cryptosporidium* in the literature sources reviewed in Chapter 2 (Section 2.9) yielded mortality estimates that we deemed outside the plausible range expected in the WBDOSS. Because the vast majority of WBDO cryptosporidiosis cases are accounted for by the Milwaukee outbreak and the case-fatality ratio for these cases is thoroughly developed in the Hoxie et al. analysis, we used the Milwaukee outbreak case-fatality ratio as the basis for developing the high estimate presented in Table 6-4. Total cryptosporidiosis deaths

[1] Hoxie et al. (1997) reported that 85% of the cryptosporidiosis-associated deaths that occurred in the Milwaukee vicinity between March 1993 and March 1995 occurred in individuals with AIDS listed as the underlying cause of death. Ideally, we would develop two case-fatality rates: one for the AIDS population and one for the general population. For this component of the upper-bound estimate, we would apply the rates separately to WBDO cases that have AIDS and the general population; however, in the absence of such data for each *Cryptosporidium* WBDO, we apply the rate to all *Cryptosporidium* WBDO cases.

TABLE 6-4

Total Number of Outbreaks and Alternative Estimates of Deaths for Each Etiologic Agent

Etiological Agent (General)	Outbreaks	Cases	Low Expected Deaths	Reported Deaths (WBDOSS)	High Expected Deaths
AGI	365	83,493	0	1	33
Viruses					
Norovirus	26	13,100	0	0	0
SRSV (assumed to be norovirus)*	1	70	0	0	0
Rotavirus*	1	1,761	0	0	0
Hepatitis A	28	827	0	0	2
Bacteria					
C. jejuni	19	5,604	0	0	8
E. coli O157:H7 & other/ *E. coli* O157:H7 & *Campylobacter*	12	1,529	2	6	48
*P. shigelloides**	1	60	0	0	0
Salmonella, non-typhoid spp.	15	3,203	0	7	25
S. enterica serovar Typhi	5	282	0	0	1
Shigella	44	9,196	0	2	18
V. cholerae	2	28	0	0	0
Yersinia	2	103	0	0	0
Protozoa					
Cryptosporidium	15	421,473	50	50	71
Cyclospora*	1	21	0	0	0
*En. histolytica**	1	4	0	0	0
Giardia	126	28,427	0	0	0
Total	665	569,962	52	66	206

AGI = acute gastrointestinal illness of unknown etiology
SRSV = small round structured virus
* Because there is only a single reported outbreak for these etiologic agents; we are relatively confident that there were no deaths associated with these outbreaks.

from all 15 *Cryptosporidium* WBDOs include the possible 19 additional deaths suggested by Hoxie et al. plus two more projected by applying the Milwaukee case-fatality ratio (50 deaths/403,000 cases) to the remaining 18,473 cases associated with the other *Cryptosporidium* WBDOs.[2]

6.2.1.2. Monte Carlo Analysis — The Monte Carlo analysis was conducted using Crystal Ball 2000 (Decisioneering, Inc., Denver, CO) and consisted of 50,000 iterations. For each pathogen, we developed a triangular distribution that was intended to depict the uncertainty in the number of deaths that might have been caused by the outbreaks attributed to a specific pathogen. The values for low expected deaths, reported deaths and high expected deaths correspond to the minimum, mode and maximum values of the probability distribution used in the Monte Carlo analysis. Rank correlation coefficients were calculated to analyze the impact of model parameters on the simulation results.

6.2.2. Results and Discussion: Uncertainty Analysis of the Deaths Associated with the WBDO. Figure 6-1 shows that the number of deaths predicted ranged from 63 to 169 in this analysis. The mean of the distribution is 108 deaths and the 10^{th} and 90^{th} percentile values are 88 and 129 deaths, respectively. Comparing the reported totals (Table 6-4, column 6) to upper-bound totals shows that at the upper end of the distribution there are over 3 times more deaths than are listed in the reported data (column 5). The lower-bound values were only 23% less than the reported values, which is expected because we used the same estimate for the low and reported mortality values (n=50).

We considered conducting an additional Monte Carlo analysis that evaluated each epidemiologic measure and each monetary measure, but doing this was not possible because we did not identify any studies on a national scale that systematically evaluated the uncertainty and variability in distributions of the COI measures for the morbidities associated with U.S. waterborne diseases. Although the data listed in Table 4-1 could have served as a primary source of information for the development of the COI distributions, we determined that there were insufficient data on which to develop meaningful distributions. In general, the studies described in Table 4-1 present only "central tendency" values for each COI measure as reported from different studies.

[2] Craun et al. (2001), Craun and Frost (2002), and Hunter and Syed (2001) suggest that it is possible for the Milwaukee case estimate (Mac Kenzie et al., 1994) to be subject to recall bias. If the 403,000 cases estimated to have occurred during the Milwaukee WBDO is an overestimate, then the case-fatality rate could be higher than this rate.

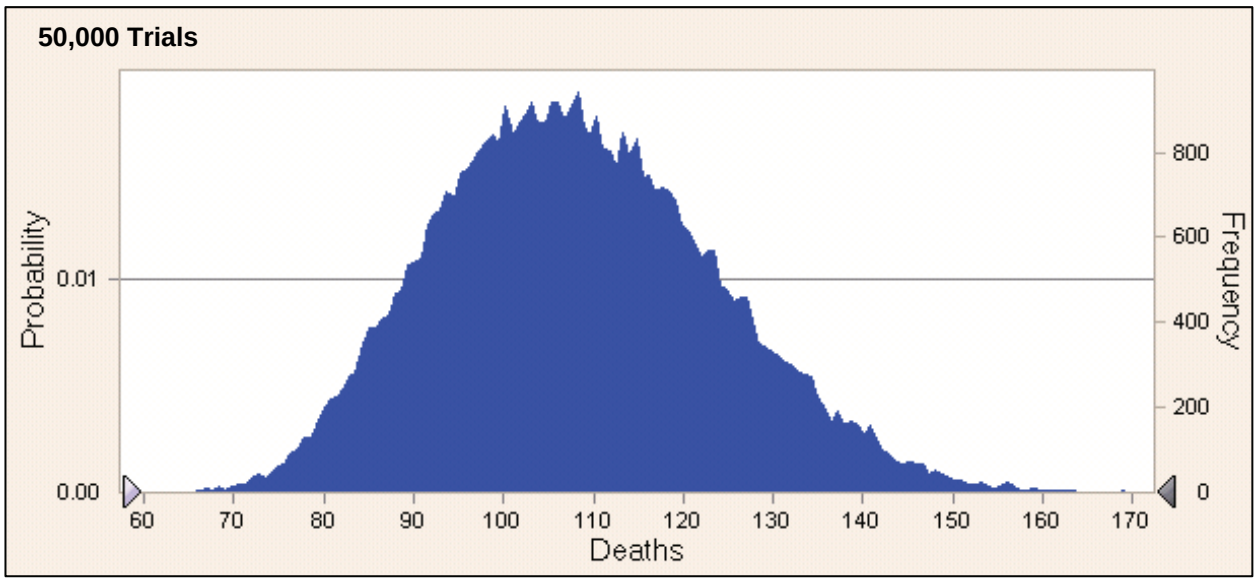


FIGURE 6-1

Predicted Distribution of U.S. WBDO Deaths Based on Monte Carlo Simulations with Distributions of the Numbers of Deaths for all Etiologic Agents

While we were confident in the estimates of the central tendencies, we had little confidence in the information describing the variability around these estimates. If we developed an analysis based only on the distribution of these central tendency measures but did not capture appropriately the spread of these data, then the analysis would underestimate the potential impacts of the uncertainty in these data.[3]

6.3. SENSITIVITY ANALYSIS OF THE MONETARY BURDEN ASSOCIATED WITH THE MILWAUKEE OUTBREAK TO THE REPORTED DURATION OF ILLNESS AND CASE NUMBER

This sensitivity analysis examined the impact of changes in two epidemiologic burden components, case number and illness duration, on the monetary burden estimate. These two components account for much of the monetary burden associated with the 665 WBDOs. Both the duration of illness and the number of cases of illness are needed to compute the person-days ill, which is then used to estimate the monetary burden associated with lost productivity. Section 6-1 shows that these two components require a magnitude change of 7% to change the total monetary burden estimate by 5%.

Using the illness duration information presented in Table 2-1, we developed an initial sensitivity analysis to examine the influence of reported illness duration on the estimated total person-days ill associated with the WBDOs reported to the WBDOSS between 1971-2000. For each etiologic agent, we identified a minimum, a maximum and the most probable illness duration values. The most probable value was based on the central tendency estimate of the durations reported in the WBDOSS database for the agent. Assuming that these three values correspond to the 5^{th} percentile, 95^{th} percentile and median illness duration, we used a triangular distribution for the illness duration for each agent.[4] We did not change the number of cases. In the preliminary analysis, the predicted total person-days ill was most sensitive to the 95th percentile value used for the duration of illness associated with waterborne cryptosporidiosis. For example, if the 95th percentile value was 26, 21 or 9 days, the rank correlation coefficients were 0.97, 0.95 and 0.78, respectively. We note that 9 days is likely a significant underestimate of the 95th percentile of waterborne cryptosporidiosis. This result was a consequence of the duration of cryptosporidiosis and the large number of

[3] A comprehensive uncertainty analysis, while outside the scope of this effort, is clearly needed.
[4] This distribution assumes that the duration of 5% of the outbreaks are above the maximum duration reported and the duration of 5% of the outbreaks are below the reported minimum duration. These distributions assume that the reported minimum and maximum values are not the true minimum and maximum of the distribution. These distributions attempt to approximate the true underlying statistical distribution of the outbreak durations.

cases reported to the WBDOSS. Most of these cases were the result of the Milwaukee cryptosporidiosis outbreak, thus we focused our analysis on the Milwaukee outbreak.

To illustrate the impact on monetary burden, we developed several estimates of both the number of cases of illness that occurred during the Milwaukee outbreak and their average duration. We then examined the influence of these alternative estimates on the associated monetary disease burden estimated for this outbreak. The Milwaukee outbreak is well studied, making it a convenient source of published estimates for this illustrative analysis. This outbreak contributed significantly to the number of person-days ill and monetary burden due to the large number of estimated cases (403,000) and illness duration (i.e., 9 days) (Chapters 3 and 5). Most of the case number and duration estimates reported for the other WBDOs are subject to the same uncertainties described in subsequent sections for the Milwaukee outbreak (e.g., recall bias, uncertain background illness rates) and, as noted in Chapter 2, the methods we used to estimate the unreported measures are also uncertain.

6.3.1. Alternative Estimates of Duration of Cryptosporidiosis During Milwaukee WBDO. Although Mac Kenzie et al. (1994) report only a median illness duration of 9 days in the abstract of their published article, they surveyed three populations with different mean and median illness durations: (1) persons with laboratory-confirmed cryptosporidiosis, (2) persons with clinically-defined cryptosporidiosis (i.e., symptoms consistent with cryptosporidiosis) and (3) a household survey of persons with watery diarrhea (the case-definition used to identify cryptosporidiosis in Mac Kenzie et al.). The reported duration of illness among these populations ranged from 1 to 55 days (Table 6-5). Median values of 3 days duration for watery diarrhea were reported in the clinical infection and household surveys, which contrast sharply with the median duration of 9 days for laboratory-confirmed cases. Of the 285 laboratory-confirmed patients, 46% were hospitalized and 48% were immuno-compromised. These data indicate that these patients may have been among the most severe cases and had the longest lasting disease. For our main epidemiologic and monetary burden analyses, we used the reported median duration of illness of 9 days. Nine days is the typical duration of illness reported in the CDC fact sheets for cryptosporidiosis and is also the midpoint of the median durations listed for all 12 *Cryptosporidium* WBDOs (Table 6-6). In these WBDOs, the median duration reported during a *Cryptosporidium* WBDO ranged from 3 to 74 days. For this sensitivity analysis, we assumed that the average duration of cryptosporidiosis in the Milwaukee WBDO was alternatively 3 or 9 days.

TABLE 6-5

Duration of Illness, Milwaukee *Cryptosporidium* Outbreak (Mac Kenzie et al., 1994)

Population Surveyed	Duration (Days)			Survey Information
	Median	Mean	Range	
Laboratory-Confirmed Cases	9	12	1 to 55	n=285 lab-confirmed cases
Clinical Infection	3	4.5	1 to 38	n=201 respondents with watery diarrhea (482 total respondents)
Household Survey	3	-	1 to 45	n=436 interviewed with watery diarrhea (1,663 total household members)

TABLE 6-6

Distribution of Reported Median Duration of Illness of *Cryptosporidium* WBDOs, 1971 to 2000

Median Reported Duration of Illness	Number of WBDOs Reporting Median Duration Value
3.0	1
4.0	1
5.0	1
6.0	1
7.0	1
8.6	1
9.0*	1*
11.0	2
24.0	1
60.0	1
74.0	1

* Milwaukee outbreak laboratory confirmed cases

6.3.2. Alternative Estimates of Milwaukee Cryptosporidiosis Cases. The WBDOSS attributes 403,000 cases of cryptosporidiosis to the Milwaukee outbreak. This is the central estimate of the number of cases estimated by Mac Kenzie et al. (1994) in their outbreak investigation (details provided in Chapter 2). They estimated the number of people that had symptoms consistent with cryptosporidiosis during the outbreak by means of a telephone survey in which 26% of the respondents reported watery diarrhea during the period of the outbreak (defined as March 1-April 28, 1993). By applying the proportion of persons experiencing the symptom compatible with cryptosporidiosis to the total population at risk (1.61 million people), they estimated that 419,000 persons (95% confidence interval = 386,000-451,000) may have been ill during the Milwaukee WBDO (Table 6-7). After subtracting a background rate of 0.5% per month for diarrhea due to all causes (16,000 people/2-month outbreak period), it was determined that 403,000 people experienced watery diarrhea due to the cryptosporidiosis outbreak.

To develop a high-end case number estimate for burden analysis, we subtract the background cases from the value of the upper 95% confidence interval and project 435,000 cases. Although not used here, other approaches could be considered for development of a high-end estimate. For example, a study of *Cryptosporidium*-specific antibody responses in children by McDonald et al. (2001) suggests that infection may have been more widespread.[5] Naumova et al. (2003) also emphasize the importance of secondary transmission especially among children and the elderly, which could have led to additional unreported cases. The estimated 403,000 cases included only the symptomatic cases that occurred between March 1 and April 28, 1993. Given the 2-month duration of the study, we assume that this estimate consists of primary and secondary cases; however, secondary cases that occurred after this survey time period would not be included in the case estimate of Mac Kenzie et al. (1994). This estimate also would not include asymptomatic cases; while such cases could contribute to secondary spread in the population, they would not contribute to either the epidemiologic or monetary burden estimates since they would not be described by the epidemiologic measures used in our analysis.[6]

To develop a low-end estimate, we subtracted the background rate used by Mac Kenzie et al. (16,000) from their lower-bound 95% confidence interval (386,000) and estimated that the outbreak consisted of 370,000 cases. Although not used for this

[5] We note that infection does not imply that the individual was ill.
[6] We note that the issues of asymptomatic infection and secondary spread in outbreaks and their influence on outbreak size are not unique to the Milwaukee outbreak.

TABLE 6-7

Alternative Estimates of Number of Cases Attributable to the Milwaukee WBDO

Source of Background Incidence Estimate	Background Incidence (Episodes [cases] per person per year)	Background Rate (% of Milwaukee area residents[a] experiencing background [i.e., non-outbreak-related] cases of diarrhea per month)	Cases of Diarrheal Illness (computed from Mac Kenzie's survey-based estimate of 419,000 [95% CI, 386,000-451,000] cases of watery diarrhea)
Mac Kenzie et al. (1994) Upper 95% CI	0.06[b]	0.5%[b]	435,000
WBDOSS	0.06[b]	0.5%[b]	403,000
Mac Kenzie et al. (1994) Lower 95% CI	0.06[b]	0.5%[b]	370,000
Mead et al. (1999)	0.61[c]	5.1%[c]	255,317
Roy et al. (2006)	0.65[d]	5.4%[d]	244,583
Hunter and Syed (2001)	1.404[e]	11.7%[e]	42,260

[a] Greater Milwaukee area population of 1,610,000
[b] Restricted to cases of "watery diarrhea"
[c] Mean of age-adjusted incidence of episodes or cases of "any diarrhea, with or without vomiting" presented in Mead et al. as derived from 1996/97 FoodNet data (CDC, 1998b), the Cleveland study (Dingle et al., 1964), and the Tecumseh study (Monto and Koopman, 1980)
[d] Episodes or cases of AGI defined as "3 or more loose stools in a 24-hour period resulting in an impairment of daily activities or diarrhea duration greater than one day"
[e] Episodes or cases of AGI of any symptom profile ascertained from FoodNet 1997 data (CDC, 1998c)

burden analysis of WBDOSS reported cases, several other evidentiary lines could be considered for development of alternative low-end estimates of the number of Milwaukee cases. To estimate the number of cases that occurred during a WBDO, epidemiologic investigations rely on subjects' recollection of experiencing specific symptoms during a specific period of time and the identification of an appropriate background illness rate to compare with the increased disease incidence. Even though the 1993 Milwaukee cryptosporidiosis outbreak investigation (Mac Kenzie et al., 1994; Hoxie et al., 1997; Proctor et al., 1998) was quite extensive, Hunter and Syed (2001) suggest that outbreak-related cases may have been overestimated due to recall bias and the use of a background incidence rate that was too low.

The background rate assumed in the Mac Kenzie study was 0.5% per month (or 16,000 cases during the 2-month period per 1,610,000 people in greater Milwaukee—the equivalent of an annual diarrheal risk of about 0.06 cases per person per year); the source was cited as "unpublished data." Roy et al. (2006) estimated general background incidence rates of AGI in the United States to be 0.65 episodes per person-year (this would indicate 174,417 background AGI cases during the 2-month Milwaukee WBDO, a 5.0% per month rate). This background incidence rate for AGI is comparable to that that we computed (0.61 episodes per person-year) for AGI characterized by diarrhea of any type (with or without vomiting) based on the rates provided in Table 4 of Mead et al. (1999). Mead et al. evaluated retrospective community-based studies in the United States (Dingle et al., 1964 [the Cleveland study]; Monto and Koopman, 1980 [the Tecumseh study]) and 1996/97 FoodNet data, and developed age-adjusted rates of AGI with several symptom profiles. Age-adjustment was conducted because the Cleveland and Tecumseh studies over-sampled children. By considering the age-adjusted incidence of diarrheal illness provided by Mead et al., we computed an average background diarrhea incidence of rate of 0.61 cases per person-year (5.0% per month;[7] 163,682 cases per 1,610,000 people per 2-month period). Hunter and Syed, in considering the same data sets as Mead et al., suggest a background incidence rate of 11.7% per month,[8] or 376,740 cases per 1,610,000 per 2-month period—the equivalent of an annual diarrheal illness incidence of about 1.4 cases per person per year (presumably for all AGI symptom profiles and without age-adjustment). If such a background rate was representative of Milwaukee at that time, the outbreak

[7] An incidence rate of 0.61 cases per person-year/12 = 0.051 cases per person-month, i.e., a background rate of 5.0% per month.
[8] An incidence rate of 1.4 cases per person-year/12 = 0.117 cases per person-month, i.e., a background rate of 11% per month.

cryptosporidiosis cases would number only 42,260 after accounting for the higher background rate of diarrheal illness. Alternative estimates are summarized in Table 6-7.

Furthermore, recall bias may result in the reporting of more illnesses than actually occurred (Craun and Frost, 2002; Craun et al., 2001; Hunter and Syed, 2001). These researchers reason that the Mac Kenzie et al. estimate could be subject to recall bias, given the increased publicity and the primary investigators' reliance on self-reporting of non-specific diarrheal illness. Hunter and Syed point out that, according to Wheeler et al. (1999), in comparison to prospective studies, retrospective studies overestimate diarrheal illness in a community by a factor of 2.8.

6.3.3. Effect of Alternative Case Numbers and Duration of Illness on the Burden of the Milwaukee WBDO. Tables 6-8 and 6-9 present the epidemiologic burden possibilities under six alternative combinations of case number and duration of illness estimates for the Milwaukee outbreak: three different case number estimates evaluated at 3 and 9 days duration of illness. Because this analysis focuses on alternative case and illness duration estimates, the number of deaths attributed to this WBDO was not changed in any of the alternatives. The number of physician visits, emergency room visits, hospitalizations and number of cases that self-medicated are affected by changes in case number (i.e., 435,000 vs. 403,000 vs. 370,000). As the number of cases declines in these estimates, there will be a proportional decrease in these estimates. Person-days ill varies with both case number and duration of illness. For example, the number of person-days ill reported in Table 6-8 (median duration of illness is assumed to be 9 days) is three times greater than the corresponding number of person-days ill listed in Table 6-9 (median duration of illness is assumed to be 3 days).

Tables 6-10 and 6-11 show that the COI associated with these estimates for the Milwaukee outbreak could range from approximately $74 million to $165 million. The COI estimated for the median duration of three days is roughly one- half the value estimated for nine days (Figure 6-2). Tables 6-10 and 6-11, which list the results of each economic measure for each alternative outbreak, show that lost productivity of both the ill person and the caregiver account for most of the differences across the alternative COI estimates. For example, assuming that there were 403,000 cases resulting from the Milwaukee WBDO, the lost productivity for the ill is valued at $95 million if duration of illness is 9 days but only $32 million if 3 days is assumed to be the median duration.

TABLE 6-8

Alternative Estimated Numbers of Cases and Epidemiologic Burdens of the Milwaukee Outbreak Assuming 9 Days Median Duration of Illness

Alternative	Cases	Physician Visits	Emergency Room Visits	Hospitalizations	Deaths	Person-Days Ill	Cases of Self-Medication	Ill Productivity Days Lost	Caregiver Productivity Days Lost
I9	435,000	21,890	12,658	4,749	50	3,915,000	130,452	710,308	103,157
II9	403,000	20,280	11,727	4,400	50	3,627,000	120,856	658,055	95,568
III9	370,000	18,620	10,770	4,040	50	3,330,000	110,960	604,170	87,740

I9 = case number reported for upper bound of 95 percentile confidence interval in Mac Kenzie et al. and 9-day duration.
II9 = case number as reported in waterborne outbreak database and 9-day duration.
III9 = case number reported for lower bound of 95 percentile confidence interval in Mac Kenzie et al. and 9-day duration.

TABLE 6-9

Alternative Estimated Numbers of Cases and Epidemiologic Burdens of the Milwaukee Outbreak Assuming 3 Days Median Duration of Illness

Alternative	Cases	Physician Visits	Emergency Room Visits	Hospitalizations	Deaths	Person-Days Ill	Cases of Self-Medication	Ill Productivity Days Lost	Caregiver Productivity Days Lost
I3	435,000	21,890	12,658	4,749	50	1,305,000	130,452	236,769	34,385
II3	403,000	20,280	11,727	4,400	50	1,209,000	120,856	219,352	31,856
III3	370,000	18,619	10,767	4,040	50	1,110,000	110,960	201,390	29,247

I3 = case number reported for upper bound of 95 percentile confidence interval in Mac Kenzie et al. and 3-day duration.
II3 = case number as reported in waterborne outbreak database and 3-day duration.
III3 = case number reported for lower bound of 95 percentile confidence interval in Mac Kenzie et al. and 3-day duration.

TABLE 6-10

Alternative Estimated Numbers of Cases and Economic Burdens of the Milwaukee Outbreak Assuming 9 Days Median Duration of Illness

Alternative	Physician Visit Cost ($)	Emergency Room Visit Costs ($)	Hospital Costs ($)	Self-Medication Costs ($)	Cost of Ill Productivity Losses ($)	Cost of Caregiver Productivity Losses ($)	Cost-of-Illness Total ($)
I9	1,411,926	4,835,800	40,226,504	969,872	102,284,317	14,854,535	164,582,954
II9	1,308,060	4,480,063	37,270,292	898,525	94,759,953	13,761,787	152,478,680
III9	1,200,948	4,113,209	34,220,905	824,949	87,000,453	12,634,891	139,995,355

I9 = case number reported for upper bound of 95 percentile confidence interval in Mac Kenzie et al. and 9-day duration.
II9 = case number as reported in waterborne outbreak database and 9-day duration.
III9 = case number reported for lower bound of 95 percentile confidence interval in Mac Kenzie et al. and 9-day duration.
$ = all dollar estimates in 2000$

TABLE 6-11

Alternative Estimated Numbers of Cases and Economic Burdens of the Milwaukee Outbreak Assuming 3 Days Median Duration of Illness

Alternative	Physician Visit Cost ($)	Emergency Room Visit Costs ($)	Hospital Costs ($)	Self-Medication Costs ($)	Cost of Ill Productivity Losses ($)	Cost of Caregiver Productivity Losses ($)	Cost-of-Illness Total ($)
I3	1,411,926	4,835,800	40,226,504	969,872	34,094,772	4,951,512	86,490,386
II3	1,308,060	4,480,063	37,270,292	898,525	31,586,651	4,587,262	80,130,853
III3	1,200,948	4,113,209	34,220,905	824,949	29,000,151	4,211,630	73,571,792

I3 = case number reported for upper bound of 95 percentile confidence interval in Mac Kenzie et al. and 3-day duration.
II3 = case number as reported in waterborne outbreak database and 3-day duration.
III3 = case number reported for lower bound of 95 percentile confidence interval in Mac Kenzie et al. and 3-day duration.
$ = all dollar estimates in 2000$

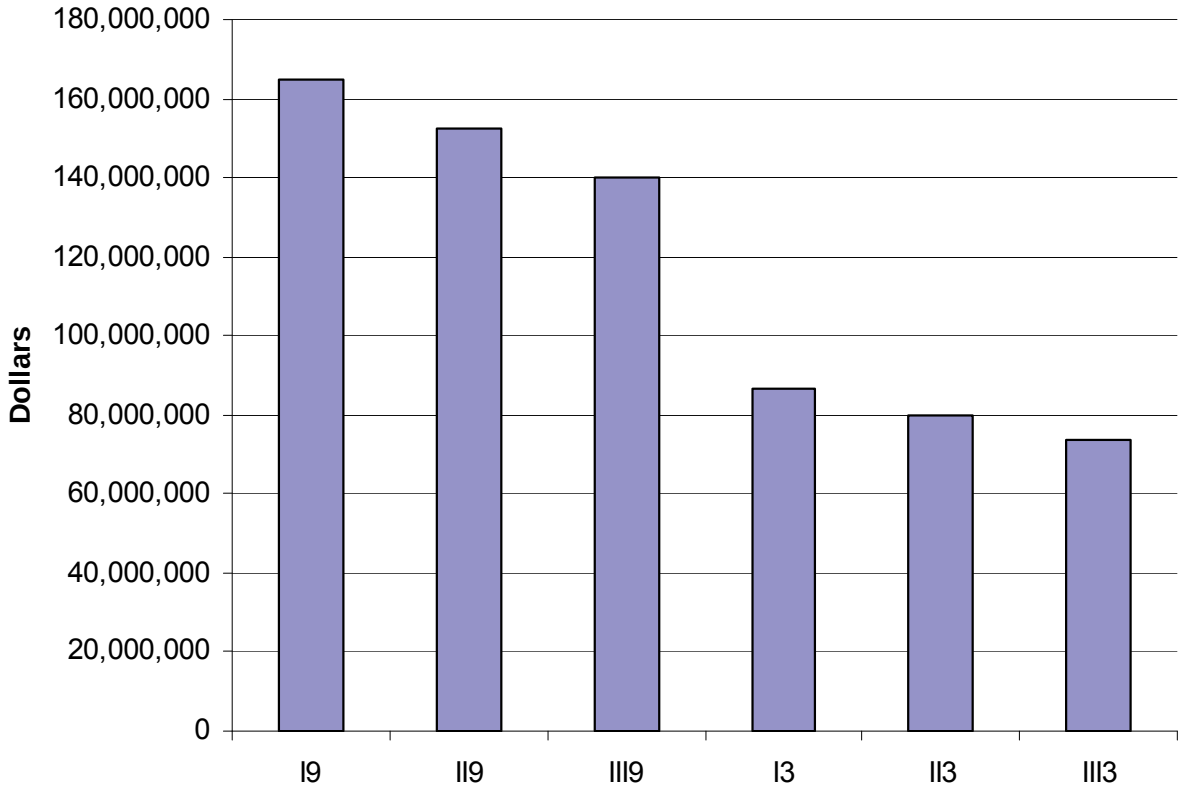


FIGURE 6-2
Cost-of-Illness Estimates Associated with Alternative Impacts of the Milwaukee Outbreak

6.4. SENSITIVITY ANALYSIS OF THE MONETARY BURDEN ASSOCIATED WITH HEMOLYTIC UREMIC SYNDROME (HUS), AN *ESCHERICHIA COLI* O157:H7 SEQUELA

In this sensitivity analysis we investigated the possible increased epidemiologic and economic burden associated with hemolytic uremic syndrome (HUS), a potential sequela of *Escherichia coli* O157:H7 (*E. coli* O157) infections. Enterohemorrhagic strain of *E. coli* are the most common cause of post diarrheal HUS, although other pathogens such as *Campylobacter* and *Shigella* can cause this sequela. Failure to consider the additional health care required to treat this severe sequela could result in an underestimate of the burden associated with outbreaks attributed to *E. coli*. We relied on other data sources to estimate the frequency of HUS occurrence with *E. coli* O157 infections and the additional costs associated with it. This potential additional burden was not examined in the primary analysis.

The pathogenicity of *E. coli* O157 was initially recognized in 1982 (Riley et al., 1983). *E. coli* O157 infection can lead to HUS, characterized by hemolytic anemia, thrombocytopenia, and renal injury (Banatvala et al., 2001). A small fraction of HUS cases progress to end-stage renal disease (ESRD), a serious chronic condition that requires lifetime dialysis or kidney transplantation and reduces life expectancy (U.S. Renal Data System, 2007). A number of deaths have been attributed HUS and can occur either during the acute stage or later as a result of ESRD. Most cases appear to be reported in children and the elderly.

The first outbreak in the U.S. attributed to *E. coli* O157 and reported to the WBDOSS occurred in 1989. Between 1989-2000, 12 outbreaks attributed to *E. coli* O157, including 1 outbreak attributed to both *Campylobacter* and *E. coli* O157, were reported to the WBDOSS.[9] The number of cases arising from these outbreaks totaled 1310. The largest outbreak involving *E. coli* O157 consisted of 781 cases of gastrointestinal illness (some of which were attributed to *C. jejuni*) and the smallest consisted of 2 cases; the median outbreak size was 24.5 cases. From the 12 outbreaks, 193 hospitalizations (14.7% of all cases) were reported to the WBDOSS. In the individual outbreaks, reported hospitalization rates ranged from 0-67% (Figure 6-3). The three largest waterborne *E. coli* O157 outbreaks where characterized by hospitalization rates of 36% (56/157), 14% (34/243), and 9% (71/781). In the primary

[9] In the WBDOSS, a total of 12 outbreaks were attributed to *E. coli* (1529 cases) and 1 to *E. coli* and *Campylobacter* (781 cases); 2310 cases were attributed to these 13 outbreaks. Between 1971-2000 one *E. coli* outbreak was attributed to strain O6:H16 and was excluded from this sensitivity analysis. This outbreak accounted for 1000 cases. Therefore, we assumed 1310 cases were associated outbreaks attributed to *E. coli* O157:H7.

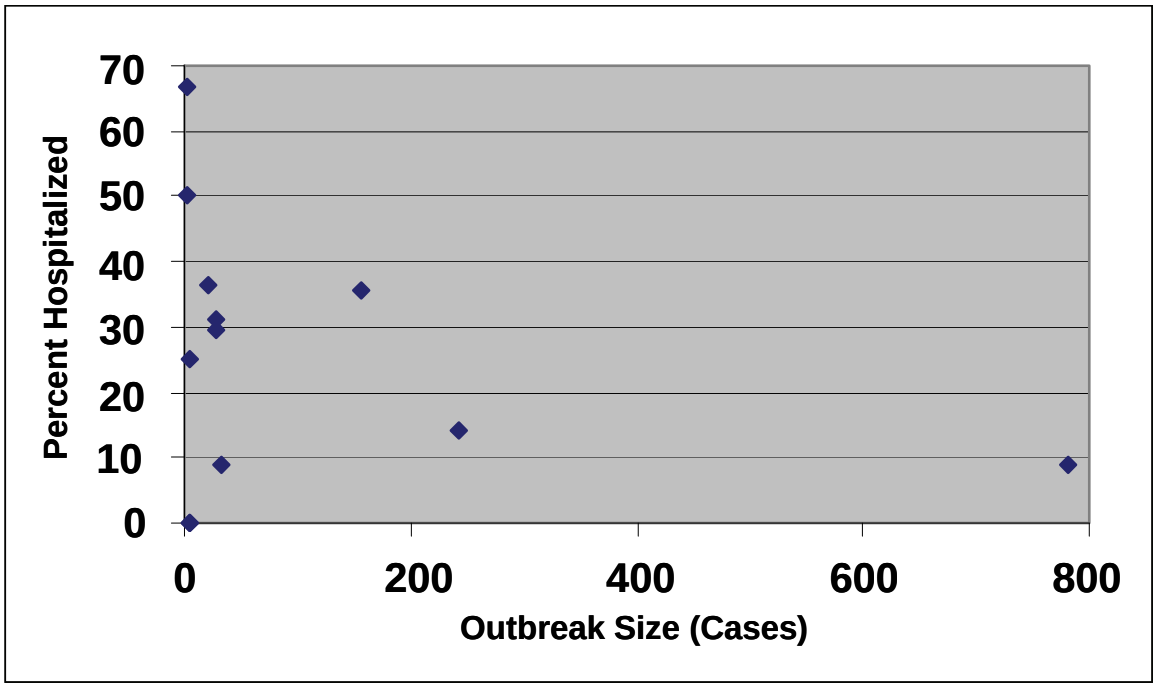


FIGURE 6-3

Outbreak Size and Hospitalization Rate for the 13 Outbreaks Attributed to *E. coli* O157:H7 Between 1989-2000 and Described in the WBDOSS Database

analysis, we estimated the costs of the 193 hospitalizations attributed to *E. coli* and *E. coli* and *Campylobacter* outbreaks to be $999,000.[10]

6.4.1. Estimated Conditional Probability of Developing HUS Associated with Cases of *E. Coli* O157. In this analysis, we developed six plausible estimates of the conditional probability of developing HUS due to an *E. coli* O157 infection. The estimates range over a factor of 10 with the lowest reported probability estimated to be 0.47% and the highest 5.6%. Using two different approaches, Frenzen et al. (2005) developed upper and lower bound estimates of the conditional probability of developing HUS. These two estimates bound the estimated conditional probabilities developed from the following three other data sources: the WBDOSS data, the Walkerton, Ontario outbreak, and Rangel et al. (2005).

Frenzen et al.'s lowest probability of developing HUS (0.47%) is the probability amongst all of the *E. coli* O157 cases (reported and not reported) estimated to occur annually in the U.S. (this is based on an estimate by Mead et al., 1999). This value was based on estimates developed from a FoodNet case-control study of O157 lab-confirmed cases and controls and a population survey of 16,435 randomly sampled residents of the FoodNet surveillance localities. They estimated that 0.41% of all *E. coli* O157 cases were hospitalized and developed HUS, 0.01% were hospitalized and both developed HUS and ESRD, 0.05% of the cases developed HUS and died. Summing the three categories, we estimated that 0.47% of all *E. coli* O157 cases are hospitalized.

The greatest probability of developing HUS (5.6%) was ascertained from linked data acquired by active FoodNet surveillance of laboratory-confirmed cases of *E. coli* O157, active surveillance of pediatric nephrologists for pediatric HUS cases, and passive surveillance for adult HUS cases at clinical labs in participating FoodNet localities. Integrating the 1997-2002 *E. coli* O157:H7 and HUS data and the *E. coli* O157:H7 patients who developed HUS suggested that 5.6% of laboratory-confirmed cases of *E. coli* O157:H7 developed HUS.

From the 12 WBDOs attributed to *E. coli* O157, the WBDOSS reports 18 cases of HUS (1.37% of all cases). At least 12 of these HUS cases were associated with the WBDO attributed to both *E. coli* O157 and *C. jejuni*. Rangel et al. (2005) attributed a total of 27 HUS cases to *E. coli* O157 WBDOs that occurred in the U.S. between 1982

[10] Table 3-2 reports 122 hospitalized cases for *E. coli* WBDO and 71 for *E. coli* and *Campylobacter* WBDO. Table 4-7 reports *E. coli* hospitalization charges of $8605 and *Campylobacter* hospitalization charges of $8027 (assuming all *E. coli* and *Campylobacter* hospitalization charges are assigned the *Campylobacter* hospitalization charge). The cost-to-charge ratio is 0.61. The product of these three estimates is $640,412 and $347,649 for the *E. coli* and *E. coli* and *Campylobacter* WBDOs, respectively.

and 2002. Rangel et al. (2005) may have had access to additional outbreak information and two of the additional nine cases they reported could have occurred after 2000. Assuming all 27 cases of HUS occurred in the 30-year period that we analyzed, 2.1% of all *E. coli* O157 cases attributed to U.S. outbreaks resulted in development of HUS.

The HUS prevalence estimate for the WBDOSS is fairly comparable to *E. coli*–HUS rates reported in other outbreaks. In the Walkerton, Ontario outbreak that occurred in 2000 and was attributed to *E. coli* O157 and *C. jejuni*, 2300 cases of disease occurred. Epidemiologic investigations attributed 27 cases of HUS (1.17%) to the outbreak. Rangel et al. (2005) report that 350 *E. coli* O157 outbreaks, involving 8598 cases, occurred in the U.S. between 1982-2000. This summary is based on outbreaks from all transmission pathways reported to CDC by state and local officials by telephone, outbreak report, or routine foodborne disease outbreak surveillance. Rangel et al. do not indicate how thoroughly the various severity indicators were reported. They attributed a total of 354 cases of HUS (4.12% of all cases) to the 350 *E. coli* O157 outbreaks.

6.4.2. Cost of Hospitalizations Associated with HUS Cases Attributed to *E. coli* O157. Frenzen et al. (2005) reported that the costs associated with a HUS hospitalization ($30,307) was six times greater than an *E. coli* O157 hospitalization without HUS ($4681)[11] (2003$) [$30,307=$26,604 in 2000$]. Using an adjustment of 0.45 for the 2001 hospital cost-to-charge ratio, Frenzen et al. estimated hospital charges based on a Nationwide Inpatient Sample. Physician costs were estimated using the 2001 Medical Expenditure Panel Survey data. Using the medical CPI we adjusted the 2003$ to 2000$ for consistency with other results. The final cost estimates were adjusted to 2000$ using the CPI for medical care [2000$=260.8 and 2003$=297.1] (U.S. Department of Labor, 2000).

6.4.3. Approach. To estimate the range of HUS cases attributable to *E. coli* O157 WBDOs, we multiplied the number of cases attributed to *E. coli* O157 in the WBDOSS (1310) by the 6 conditional probabilities of developing HUS estimated previously. We then estimated the hospitalization costs by multiplying the number of HUS cases by the costs reported in Frenzen et al. (2005) in 2000$.

[11] For comparison, Table 4-7 reports *E. coli* hospitalization charges of $8605. The product of the hospitalization charges and the cost-to-charge ratio (0.61) is $5249. The hospitalization charge estimate used by Frenzen and coauthors is approximately 10% less than the value used in the main analysis. We did not adjust the hospitalization costs of Frenzen et al. in this analysis.

6.4.4. Results. Table 6-12 shows that between 6 and 73 cases of HUS may have resulted from *E. coli* O157 WBDOs between 1989-2000. This results in a 12-fold difference between the smallest and largest conditional probabilities of developing HUS given an *E. coli* O157 infection. Figure 6-4 and the last column of Table 6-12 shows that incremental hospitalization costs associated with HUS cases that result from an *E. coli* outbreak could range from $164,000 to $1.952 million, depending on the conditional probability associated with HUS given an *E. coli* infection and assuming that the hospitalization costs are roughly a factor of 6 greater than the hospitalization costs associated with an *E. coli* infection that does not result in a HUS.

TABLE 6-12

Conditional Probability of Developing HUS Given an *E. coli* O157:H7 Infection, Estimated Number of HUS Attributable to U.S. Outbreaks Caused by *E. coli* O157:H7 Between 1989-2000 and Estimated Hospitalization Costs

Source	Conditional Probability	Predicted HUS Cases	Hospitalization Costs (2000$)
Frenzen et al. (2005) (Low)	0.47%	6	$164,000
Walkerton, Ontario	1.17%	15	$408,000
WBDOSS Reported	1.37%	18	$477,000
WBDOSS Reported and Rangel et al. Waterborne Outbreaks	2.10%	28	$732,000
Rangel et al. (2005)	4.12%	54	$1,436,000
Frenzen et al. (2005) (High)	5.60%	73	$1,952,000

WBDOSS = Waterborne Disease Outbreak Surveillance System
HUS = Hemolytic Uremic Syndrome

6.4.5. Discussion. This sensitivity analysis included a range of case estimates and hospitalization charge estimates for HUS, a sequela of *E. coli* infections. The estimated number of cases and the hospitalization charge estimates are based on data reported to the peer-reviewed literature.

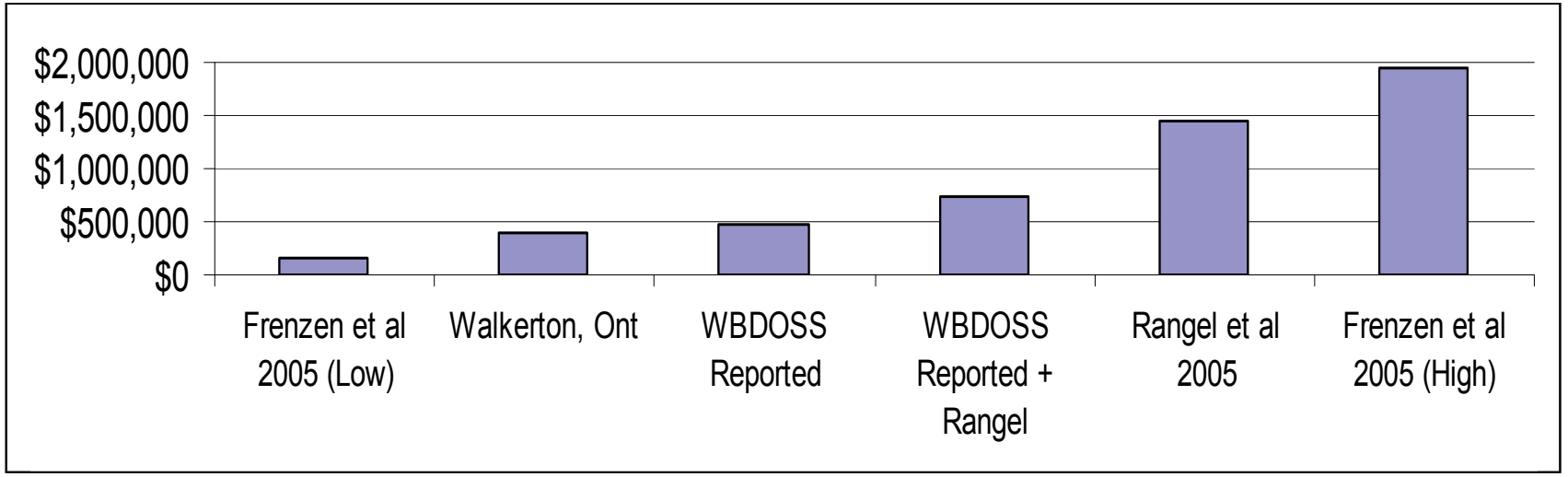


FIGURE 6-4
Range of Hospitalization Costs Estimates for HUS Cases Attributable to U.S. WBDOs (2000$)

In the main analysis, *E. coli* hospitalization costs were estimated to be $640,000 and $373,000 for the *E. coli* and *E. coli* and Campylobacter WBDOs, respectively. The sum of these hospitalization costs is $1,013,000. If added to the hospitalization cost, the lowest HUS estimate ($164,000 associated with a conditional probability of 0.47%) increased the hospitalization component of the COI for *E. coli* from $988,000 to $1.17 million, an increase of 16%. The largest conditional probability (5.6% associated with $1.952 million hospitalization costs) increased the hospitalization component of the COI for *E. coli* from $1,013,000 to $2.965 million, an increase of 193%. From the perspective of the monetary burden, this analysis highlights the potential importance of capturing the number of cases of chronic sequelae that result from an outbreak and the cost-of-illness associated with such cases; for example, this analysis did not examine the lost productivity associated with HUS.

6.5. CONCLUSIONS OF SENSITIVITY ANALYSIS

This chapter describes four separate examinations of the uncertainty associated with the monetary burden estimate. The first analysis demonstrates how changes in the various epidemiologic measures (e.g., total hospitalizations, total person-days ill) would alter the total monetary burden estimate. Relatively small changes in the number of person-days ill would bring about a 5% difference in the total burden, illustrating that case numbers and duration of illness are the most influential factors in these burden estimates, as calculated in the main analysis. In contrast, the overall magnitude of the medical treatment components (i.e., numbers of hospitalizations, physician visits and emergency room visits) would have to be markedly different from the estimated values to affect the total burden to a significant degree. The results of the first sensitivity analysis suggest that uncertainty in the numbers of cases and in the duration of illness are of much greater concern than the uncertainty in the medical treatment factors. We note that the monetary burden analysis did not evaluate the impact of deaths on the monetary burden estimate. Depending on the approach used to estimate the costs associated with such outcomes, this could be a substantial component of the monetary burden.

The second and third analyses were conducted because the information needed to develop a comprehensive uncertainty analysis was not available. As noted previously, while we are confident in the central tendency measures, we were unable to develop distributions that we deemed adequate for this analysis. The development and publication of data sets for the costs associated with the various morbidities that result from a WBDO is a clear research need. Valid methods to quantify plausible

distributions of the illness durations, physician visits, emergency room visits and hospitalizations associated with WBDOs are needed as are approaches for estimating the monetary burden associated with deaths that have already occurred.

In the second analysis, we developed a distribution of the number of deaths associated with each pathogenic agent and for AGI. The distribution of deaths associated with each agent led to a relatively narrow distribution of plausible range of deaths (88-129) associated with U.S. outbreaks.

The third analysis focused on the impact of alternative case and duration estimates during the 1993 Milwaukee cryptosporidiosis outbreak, which was responsible for the majority of the monetary burden estimate. The analysis showed that, if a 3-day average duration of illness was used instead of a 9-day duration, then the monetary burden would decrease by approximately one-half. For the 9-day duration, decreasing case estimates by 8% (403,000 vs. 370,000) resulted in total monetary burden estimates that were 8% lower than those based on the reported values. The same case reductions for the 3-day duration showed 8% lower monetary burden estimates for the Milwaukee WBDO. This further highlights the importance of the contribution of person-days of illness and lost productivity to the monetary burden associated with this outbreak.

The fourth analysis focused on the impact of chronic sequelae on the estimated COI associated with hospitalization costs. Using a range of literature-based estimates for the conditional probability of developing HUS following an *E. coli* gastrointestinal infection, we estimated that from 6-73 HUS cases could have resulted from the *E. coli* outbreaks. At the lower end ($164,000), these could increase the estimated hospitalization costs associated with *E. coli* outbreaks by approximately 20% and, at the upper end ($1.952 million), these could increase these hospitalization costs by 193%. At the upper end, these increase the total COI associated with all outbreaks ($201,716,000) by about 1%. It increases the COI associated with *E. coli* and *E. coli* and *Campylobacter* outbreaks ($1.658 million) by 118%. This highlights the importance of collecting chronic sequela data for outbreaks and shows the potential increase associated with including sequela from one agent.

7. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

We examined the epidemiologic and monetary burden from waterborne outbreaks reported in the U.S. from 1971 to 2000. Monetary burden estimates were based on epidemiologic measures recorded in the WBDOSS including the number of cases of illness, illness duration, hospital admissions, physician visits, and emergency room visits. We estimated unreported severity measures such as illness duration and the number of physician and emergency room visits based on data available from published literature or, preferably, from other outbreak data in the WBDOSS. We also examined the sensitivity of the total disease burden estimate to various assumptions (e.g., illness duration in the Milwaukee outbreak, a severe sequela such as hemolytic uremic syndrome (HUS) from *E. coli* infections, etc.) in order to address some of the uncertainty in the results. Although we did not monetize the reported number of deaths attributed to waterborne outbreaks, we used a sensitivity analysis to examine the potential impact of under- and over-reported deaths from reported outbreaks in the WBDOSS.

7.1. DISCUSSION

The total estimated monetary burden from the 665 outbreaks reported to the WBDOSS from 1971-2000, including approximately 570,000 cases of illness and over 4.5 million person-days ill, was $202 million. This was based on a cost-of-illness (COI) analysis, which included cost estimates related to morbidity including medical expenses and productivity loss (i.e., days lost for work valued by lost wages and household production for the sick individual and their caregivers). Similar to the Corso et al. (2003) analysis of the Milwaukee cryptosporidiosis outbreak, productivity losses for the ill and their caregivers accounted for more than two-thirds of the COI disease burden estimate for outbreaks during 1971-2000.

The number of cases ill and the duration of illness were used to calculate person-days ill attributable to waterborne outbreaks. The majority of outbreak cases and estimated person-days ill occurred in surface water systems. This was mostly due to the Milwaukee cryptosporidiosis outbreak, which contributed 403,000 of the 570,000 cases recorded in the WBDOSS from 1971 to 2000. Given the magnitude of the Milwaukee outbreak and its impact on the overall disease burden, we examined the epidemiologic burden associated with and without the Milwaukee outbreak. Without the Milwaukee outbreak cases, the reported number of cases of illness in groundwater

systems was twice as large as the number in surface water systems while person-days ill estimates were slightly higher in surface water systems.

Community systems served over 264 million persons in the U.S. in 2000, including 178 million people who relied on surface water for their drinking water (U.S. EPA, 2001). Groundwater serves over 111 million people in the U.S. and is the primary source for most non-community water systems. Although they serve fewer than 25 million people in the U.S., non-community systems accounted for the majority (n=329) of the reported outbreaks. Despite the greater frequency of outbreaks in non-community systems, most of the epidemiologic burden occurred in community water systems irrespective of whether Milwaukee was considered. After excluding Milwaukee, reported cases in non-community and community system outbreaks were fairly comparable, but the person-days ill estimate remained more than twice as large in community systems. This is likely due in part to longer average duration of protozoan infections, which largely occur in surface water-supplied community water systems. In contrast, the shorter duration of illness reported for outbreaks from non-community systems is consistent with a viral etiology more commonly found in groundwater outbreaks (Borchardt et al., 2003). Overall, the total monetary burden associated with community outbreaks was nine times larger than non-community systems with the Milwaukee outbreak included and approximately 1.5 times larger without Milwaukee.

Among the 300 outbreaks of known etiology, 143 were attributed to protozoa, 101 to bacteria and 56 to viruses. After excluding Milwaukee, protozoan outbreaks accounted for nearly 47,000 cases of illness. This was more than two and three times the reported cases from bacterial and viral outbreaks, respectively. The person-days ill estimate for protozoan outbreaks was 463,000, more than three times higher than the combined estimate for both viral and bacterial outbreaks. The 365 AGI outbreaks accounted for over 83,000 reported cases of illness and an estimated 265,000 person-days ill.

The ability for passive waterborne outbreak surveillance systems to accurately estimate the different epidemiologic measures is critical for the burden estimates that were developed. We extrapolated significant amounts of emergency room and physician visit data based on data for other agents/etiologic groups reported in the WBDOSS. The impact of these extrapolations on burden estimations is not only important at the individual outbreak level, but incomplete reporting of epidemiologic data could distort some of the comparisons that were made by etiologic agent grouping. For example, only one rotavirus outbreak was reported to the WBDOSS during the 30-year period. Since rotavirus was the only viral outbreak other than Hepatitis A with reported

physician visits, the rotavirus data was used to estimate physician visits for other viruses such as norovirus and small, round structured viruses (assumed to be norovirus). If the epidemiologic measures for the rotavirus outbreak are inaccurate or not representative of typical outbreaks reported in the WBDOSS, the impact of these errors would be compounded by their use in estimating measures for other viral outbreaks. Since data limitations resulted in the estimation of unreported measures based on other outbreaks with similar etiology (or etiologic group), we urge caution in the interpretation of these findings.

The disease burden estimates presented in this report are dependent on the extent to which outbreaks were investigated, detected, reported and recorded in the WBDOSS. The likelihood that an outbreak is detected and recorded is dependent on local and state disease surveillance capabilities as well as a variety of factors including water service system and source water type. For small non-community water systems that serve part-time or transient populations and non-residential areas, there is an increased likelihood that some outbreaks may go undetected due to insufficient clustering of cases (Lee et al., 2002). Outbreaks may also go undetected in larger communities due to factors such as decentralized health care systems and the reliance on numerous, non-integrated laboratory facilities (Board on Life Sciences, 2004). Outbreaks that result in mild symptoms, have low attack rates or are not caused by an easily identifiable etiologic agent are also more likely to go unrecognized. Because we do not consider unrecognized or unreported outbreaks that may have occurred during 1971-2000 when estimating disease burden, our results likely underestimated the actual burden attributable to waterborne outbreaks.

In our burden analyses, we did not attempt to identify likely etiologic agents for outbreaks categorized as AGI; however, we did examine the frequency of AGI outbreak by water system type. Since most of the AGI outbreaks occurred in groundwater systems, a viral origin is suspected for most of these outbreaks (Barwick et al., 2000; Lee et al., 2002). Recent advances in molecular methods have increased the likelihood that viruses will be detected, but linking outbreaks to viruses remains a challenge since clinical specimens and water samples are still not routinely examined for viruses (Blackburn et al., 2004; Yoder et al., 2004). We, therefore, expect considerable uncertainty in the disease burden estimates for viruses due to the likelihood that many of the AGI outbreaks are of viral etiology and the possibility that viral illnesses are less effectively captured by surveillance systems compared to protozoan or bacterial illness cases (Wheeler et al., 1999).

The ability of the passive WBDOSS to capture the true magnitude of the disease burden in the U.S. is limited given the presumed under-reporting of outbreaks and variability in thoroughness and rigor in reporting of epidemiologic data for different outbreaks. Case number reports for individual outbreaks are dependent on the capacity of local public health agencies and laboratories to identify cases and link these in a timely manner to a common source of exposure to an etiologic agent. Case enumeration is also impacted by the nature of the illness occurring during an outbreak. Since waterborne infectious disease often manifests as gastroenteritis or another self-limiting illness with mild symptoms, only a small proportion of cases may seek medical attention, thereby limiting the number of ill persons that are reported to a disease surveillance system. For example, the FoodNet survey of 14,647 U.S. residents conducted during 2000-2001 indicated that 5% of those surveyed reported acute diarrheal illness during the previous four weeks (Imhoff et al., 2004). Only 23% of those who were ill visited a health care provider, and 17% of those seeking medical care reported submitting a stool specimen for culture. This indicates that only 4% of those who were ill were asked to submit a stool sample, greatly limiting the likelihood of identifying an etiologic agent for most cases for acute gastrointestinal illnesses.

Although mild cases of disease may frequently go unreported, they could represent a large portion of the disease burden from waterborne outbreaks. Corso et al. reported that mild cases accounted for nearly 43% of the total disease burden (based on the COI analysis) from the Milwaukee outbreak. This may not be representative of other outbreaks that are less thoroughly investigated, since an estimated 88% of the mild cases did not seek medical care (Corso et al., 2003). Garthright et al. (1988) estimated the total costs from medical expenses and lost productivity associated with mild gastrointestinal illness in the U.S. during 1985 at $44.9 billion for cases with no physician consultation, $6.3 billion for cases with physician consultation and $1.7 billion for cases requiring hospitalization (cost estimates were adjusted to 2000 U.S. dollars using the consumer price index for medical care noted in Chapter 4). Since severity of disease measures for outbreak cases are not reported in the WBDOSS, we designated a proportion of cases in each category based on the limited mortality and health care utilization data available in the database. For the COI analysis, we defined severe cases as individuals who died or were hospitalized due to an infection related to a waterborne outbreak (see Chapter 4 for further information). Moderate cases included individuals who visited emergency rooms or physicians and mild cases included the remaining reported cases of illness. Our disease burden approach adjusted for under-reported emergency room and physician visits but did not consider under-reporting of

mild cases. The degree of under-reporting among mild cases could not be estimated since most of these cases do not seek medical attention, which limited our ability to stratify the disease burden analyses by severity of illness categories.

The cases of illness reported to the WBDOSS most likely include acute cases of gastrointestinal disease and, therefore, our analyses likely underestimate the burden associated with complications of infections (e.g., HUS following *E. coli* O157). Our sensitivity analysis suggested that 6 to 73 of the 1310 *E. coli* cases reported to the WBDOSS may have developed HUS had there been additional follow-up of these outbreak cases. This had a significant effect (193% increase) on the estimated hospitalization costs for reported *E. coli* outbreaks, although the overall impact on the total COI increased was minimal (1% increase). This analysis demonstrated that consideration of one type of chronic sequela due to waterborne infections could have a large impact on etiologic group or agent-specific analyses including stratified analyses (e.g., by water system and source water type). These data illustrate the potential increase in disease burden associated with including sequelae from one agent, however the limited data typically collected and reported in outbreak investigations preclude additional analysis for specific pathogens or outbreaks. This burden analysis and additional sensitivity analyses would be further strengthened if data were available on susceptible populations (e.g., children, elderly, HIV/AIDS patients, etc.) who are most prone to chronic sequelae. Unfortunately, the lack of data on immune status and infrequent reporting of age in the WBDOSS database also limits the ability to quantify effects of chronic waterborne infections that have occurred in susceptible populations.

Accurate case enumeration is contingent on a thorough epidemiologic investigation and quantification of the total population exposed during an outbreak. In addition to actual reported case counts in the WBDOSS, local investigators may provide an estimated count based on the reported attack rate and information on the population exposed to the suspected contamination source. Since this information is not always known for each outbreak, this results in variability in the case estimation approach across outbreaks. We used the number of cases of illness per outbreak as reported in the WBDOSS, including the actual counts reported for 70% of the outbreaks. Twenty-two percent of the outbreaks were based on estimated counts, and the method used to enumerate cases was unknown for the remaining outbreaks (8%). Using the actual reported case numbers may lead to under-reporting in some of the outbreaks since most investigations do not identify all of the exposed or ill individuals. Identification of cases of illness can also be affected by the magnitude of and publicity surrounding an

outbreak as over-reporting of infectious disease symptoms has been previously noted in retrospective epidemiologic studies (Wheeler et al., 1999).

We examined the potential for under- and over-reporting of gastroenteritis cases associated with the Milwaukee cryptosporidiosis outbreak and also assessed the impact of variable disease severity estimates for average duration of illness. This outbreak accounted for $152 million of the $202 million total burden for all reported outbreaks during 1971-2000 and was based on 403,000 reported cases, nine days average duration of illness and a monthly background diarrheal incidence of 0.5% among residents of the greater Milwaukee area. Given the magnitude of burden attributable to the Milwaukee outbreak, we examined the extent that alternative case estimate and illness duration values would impact the overall burden. If a case estimate of 370,000 and disease duration of three days is assumed, the alternative disease burden was $74 million. If a case estimate of 435,000 and disease duration of nine days is assumed, the alternative disease burden was $165 million. Based on these alternative estimates, the Milwaukee outbreak would still account for most of the monetary burden estimated from reported waterborne outbreaks. This is largely due to the impact of the large number of cases ill and person-day ill estimates from this outbreak.

Most of the cases of illness reported to the WBDOSS were assumed to be primary cases, but we could not distinguish the extent to which secondary cases due to person-to-person transmission impacted the number of reported cases. The likelihood that secondary cases were detected and reported in epidemiologic outbreak investigations is dependent on the latency and incubation periods of the etiologic agent and the time frame of the outbreak investigation. Outbreak investigations with longer duration including those based on retrospective community surveys are more likely to detect secondary cases unless specifically restricted in time or scope to target primary cases. For example, secondary transmission in the Milwaukee outbreak has been estimated at 10% for the general population (Eisenberg et al., 2005) and was likely more prevalent among the elderly (Naumova et al., 2003). While extensive epidemiologic investigations may better reflect the true magnitude of an outbreak, including secondary cases in the case number estimates may limit comparisons of the disease burden across etiologic agent groups and may limit the potential to generalize reported epidemiologic measures to outbreaks with limited or missing data.

The magnitude of under- or over-reporting of epidemiologic measures in the WBDOSS is unknown; therefore, we used sensitivity analyses to examine the extent that under- or over-reporting may influence our monetary estimates. We demonstrated that the total monetary burden was most sensitive to estimates of person-days ill and

hospitalizations. The influence of person-days ill, largely due to its use in productivity loss calculations for both caregiver and the ill person, accounted for most of the COI contribution to disease burden. These data further emphasize the need for accurate estimation of the number of cases and the duration of illness for waterborne outbreaks since they determine the contribution of person-days ill to disease burden estimates.

Although disease burden estimates are likely quite sensitive to the large monetary value generally ascribed to saving one generic life, our analysis did not incorporate mortality attributed to waterborne outbreaks into the monetary burden calculations. We did, however, assess the potential reporting error in mortality associated with the reported outbreaks since very few outbreak investigations have the necessary resources to examine hospital records, to follow-up cases (to ascertain any chronic disease or mortality attributable to the outbreak), or conduct secondary analyses of death certificates.

There were a number of limitations related to estimating the monetary burden described in Chapter 4; many due to the lack of economic studies that could be utilized for this analysis. The direct costs used to calculate the COI did not include certain categories of expenditures (see Figure 4-1). Specifically, the estimates do not include the other costs of seeking care such as transportation and costs of hiring caregivers. Nor do they include the costs of protective or averting behaviors (i.e. defensive expenditures) such as bottled water or point-of-use filtration. Specialty physician fees, which are not included in the hospitalization costs, were also not part of the COI analysis. The assumption that medical treatment administered and costs for gastrointestinal illnesses have remained constant across years is another limitation of the COI analysis. The productivity loss component of the COI calculations also assumed that the values reported by Corso et al. (2003) are reflective of other pathogens. This would also add to the uncertainty of the monetary estimate of disease burden for reported waterborne outbreaks in the U.S.

7.2. CONCLUSIONS

In addition to mandating actions to improve the microbiological quality of water, the 1996 amendments to the SDWA also mandated benefit-cost analyses for newly proposed regulations. Estimates of the incidence and severity of diseases attributable to drinking water as well as an assessment of the social and economic costs of the occurrence of these diseases are essential for the conduct of benefit-cost analyses. Three approaches are typically used to develop a waterborne disease incidence estimate: (1) using risk assessment methods that utilize pathogen exposure information

and dose-response algorithms, (2) generalizing epidemiologic study results to the general population, and (3) analyzing public health surveillance data. These approaches, along with examples of estimates of endemic waterborne risks, are discussed in detail in a special issue of the *Journal of Water and Health* published in 2006.

Economic analyses of new water regulations in the U.S. primarily focus on evaluating endemic disease incidence that occurs when treatment and distribution systems are functioning according to established practices (i.e., not under treatment failure or deficiency situations). The U.S. EPA has largely relied on risk assessment methods to develop the endemic disease incidence estimates needed for benefit-cost analyses of proposed drinking water regulations. In the future, these risk assessment estimates of burden will be complemented and strengthened by the SDWA-mandated "national estimate" of waterborne disease. This mandate requires the U.S. EPA and the CDC to jointly conduct pilot waterborne disease occurrence studies in at least five major public water supply systems (U.S. EPA, 1998); one study already conducted has used an epidemiologic intervention study design approach (e.g., Colford et al., 2005).

In contrast to those Agency efforts focused on examining the endemic disease burden, we demonstrate a methodology for assessing the burden associated with waterborne outbreaks. Our methodology relies on the third method described above for estimating disease burden: analyzing surveillance data. Although this approach, like the others, is affected by the accuracy of available data and the limitations of the methodology that was developed, it provides additional insight for evaluating the overall burden of waterborne disease in the U.S. This analysis provides a range of estimates of the burden of reported waterborne outbreaks from 1971-2000 which may only represent a fraction of the actual waterborne outbreaks in the U.S. Nonetheless, this information contributes to the body of knowledge that regulators need for informed decision-making regarding waterborne contaminants. The disease burden approach presented here allows for comparison of disparate public health concerns through metrics that incorporate indicators of disease severity, costs and societal values. The analysis presented here also examined the potential utility of using passive surveillance systems to develop disease burden estimates for reported waterborne outbreaks; the outcome of this examination reinforces the importance of collecting more detailed epidemiologic data, including disease severity measures to aid future disease burden efforts.

A main limitation of the analyses was the inability to determine the potential impact of unrecognized and unreported outbreaks. Additional analyses could help

identify the important characteristics of unrecognized outbreaks that may aid in the estimation of the potential impact of unrecognized and unreported outbreaks on waterborne disease burden. Developing categorization approaches for determining the likely etiologic agent or group associated with AGI outbreaks would also help to further refine the disease burden estimates that are presented here. These efforts could help address some of the uncertainty in the waterborne disease burden developed here.

7.3. RECOMMENDATIONS

This analysis was useful for determining the utility of the WBDOSS for estimating waterborne disease burden. To address some of the uncertainty in the disease burden estimates, additional data are needed including specific improvements in the epidemiologic data collected and reported to the WBDOSS. The following recommendations are suggested to improve waterborne disease burden estimates in the future:

- Information needed to determine disease burden should be specifically requested on CDC 52.12. This includes the age distribution of the identified cases and frequency of healthcare utilization data (e.g., physician visits, emergency room visits, etc) on an individual level.
- Efforts are needed to standardize outbreak reporting to allow for comparisons of disease burden between reported outbreaks (e.g., an electronic reporting system). Information should also be requested about the method used to determine the number of actual and estimated cases for each outbreak.
- Information, especially that ascertained during secondary (i.e., post-outbreak analyses that follow an outbreak analysis) analyses, should also be requested about the method used to determine the epidemiologic measures for each reported outbreak. Suggested questions include: Were hospitalizations based on admission or discharge diagnosis? Was infection from the waterborne source a contributing cause or the underlying cause of death? What time period was considered for the outbreak investigation? How many cases were interviewed to obtain the illness duration information?
- Additional focused studies in selected outbreaks could improve the estimates of the number of mild cases not seeking formal care and the costs (e.g., self-medication and productivity losses) associated with them.
- Additional efforts, such as linking disease surveillance systems with water quality monitoring systems, are needed to examine the effectiveness of current water quality surveillance activities.
- Studies should be designed and conducted to assess the effectiveness of the current WBDOSS in detecting waterborne disease outbreaks.

- Studies should also be conducted to help estimate the number and type of outbreaks that may be unrecognized.
- Death certificate analyses should be conducted among sensitive populations for severe outbreaks to determine increases in mortality that may be attributable to waterborne disease outbreaks.
- An approach should be developed that is consistent with economic theory and Agency policy to estimate the monetary burden from mortality data.
- Studies should be conducted to assess case-level costs for monetary burden analyses.

In addition to the aforementioned recommendations, additional sensitivity analyses are needed to examine the effect that alternative assumptions might have on the disease burden estimates presented here. This could help identify the components that have the greatest potential impact on disease burden and could further delineate specific research needs for the future.

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APPENDIX A
THE WATERBORNE OUTBREAK SURVEILLANCE SYSTEM

A.1. INTRODUCTION

National statistics on waterborne outbreaks have been compiled and reported in the United States since 1920. In 1971, the CDC, the U.S. EPA, and the Council of State and Territorial Epidemiologists began a collaborative, passive surveillance program for the collection of data on the occurrence and causes of waterborne. State, territorial, and local public health agencies have the primary responsibility for detecting and investigating waterborne outbreaks, and they voluntarily report them to the CDC on Standard Form 52.12.[1] Occasionally, the CDC and U.S. EPA are invited to participate in the investigation.

The standard reporting form, which has been used since 1974, solicits data on the characteristics of the outbreak (including the number of ill persons, dates of illness onset, and location that define the outbreak), results from epidemiologic studies, testing of water and patient samples, and contributory issues, such as water distribution, disinfection, and environmental factors. CDC annually requests reports from state and territorial public health agencies, and from the Freely Associated States (including Republic of Marshall Islands, Federated States of Micronesia, and Republic of Palau). Additional information regarding the water quality, water system and treatment is obtained from the state's drinking water agency as needed.

Surveillance summaries of reported waterborne outbreaks have been published biennially or annually since 1973 (CDC, 1973, 1974, 1976a,b, 1977, 1979, 1980, 1981, 1982a,b, 1983, 1984, 1985; St. Louis, 1988; Levine and Craun, 1990; Herwaldt et al., 1991; Moore et al., 1993; Kramer et al., 1996; Levy et al., 1998; Barwick et al., 2000; Lee et al., 2002; Blackburn et al., 2004). The surveillance system includes outbreaks associated with drinking water, recreational water, and other types of water exposures. Numerical and text data are abstracted from the outbreak form and supporting documents and entered into a database maintained by CDC and U.S. EPA. For the analyses in this report, we used information from drinking water outbreaks reported during the 30-year period 1971-2000. Although surveillance information was recently made available for 2001-2002, the detailed information was not readily available for our analyses.

[1] The various forms used during 1971-2002 are shown at the end of the Appendix. The current form can be found at www.cdc.gov/healthyswimming/downloads/cdc_5212_waterborne.pdf.

A.2. USES OF THE WATERBORNE OUTBREAK SURVEILLANCE DATA

WBDO surveillance efforts have the following objectives: (1) characterize the epidemiology of waterborne outbreaks; (2) identify the etiologic agents that caused waterborne outbreaks and determine why the outbreaks occurred; (3) encourage public health personnel to detect and investigate waterborne outbreaks; and (4) collaborate with local, state, federal, and international agencies on initiatives to prevent waterborne disease. The surveillance data have been helpful in identifying the important waterborne pathogens and evaluating the relative degrees of risk associated with different types of source water and systems, the adequacy of current technologies and regulations (Lee et al., 2002; Blackburn et al., 2004).

A.2.1. Classification of Waterborne Outbreaks and Water Systems. Two criteria must be met for an event to be defined as a waterborne outbreak (Lee et al., 2002; Blackburn et al., 2004). First, two or more persons must have experienced a similar illness after exposure to water. This criterion is waived for single cases of laboratory-confirmed primary amebic meningoencephalitis and for single cases of chemical poisoning if water-quality data indicate contamination by the chemical. Second, epidemiologic evidence must implicate water as the probable source of the illness. Epidemiologic evidence is important because waterborne pathogens of concern in the United States may have multiple transmission routes, including person-to-person contact, contact with fomites, and ingestion of contaminated food as well as contaminated water. The evidence must associate water with illnesses before it can be considered as a waterborne outbreak.

The CDC and U.S. EPA classify reported waterborne outbreaks according to the strength of the evidence implicating water as the vehicle of transmission (Lee et al., 2002; Blackburn et al., 2004). The classification scheme is based on the epidemiologic and water-quality data provided by the investigators. Epidemiologic data are weighted more than water-quality data. Although outbreaks without water-quality data might be included, reports that lack epidemiologic data are not. Single cases of primary amebic meningoencephalitis or chemical poisoning are not classified according to this scheme. The classification system was developed in 1989 (Herwaldt et al., 1991). Before 1989, an informal, but similar, approach was used to evaluate the evidence. A classification of I indicates that adequate epidemiologic and water-quality data were reported (Table A-1); however, “the classification does not necessarily imply whether an investigation

TABLE A-1

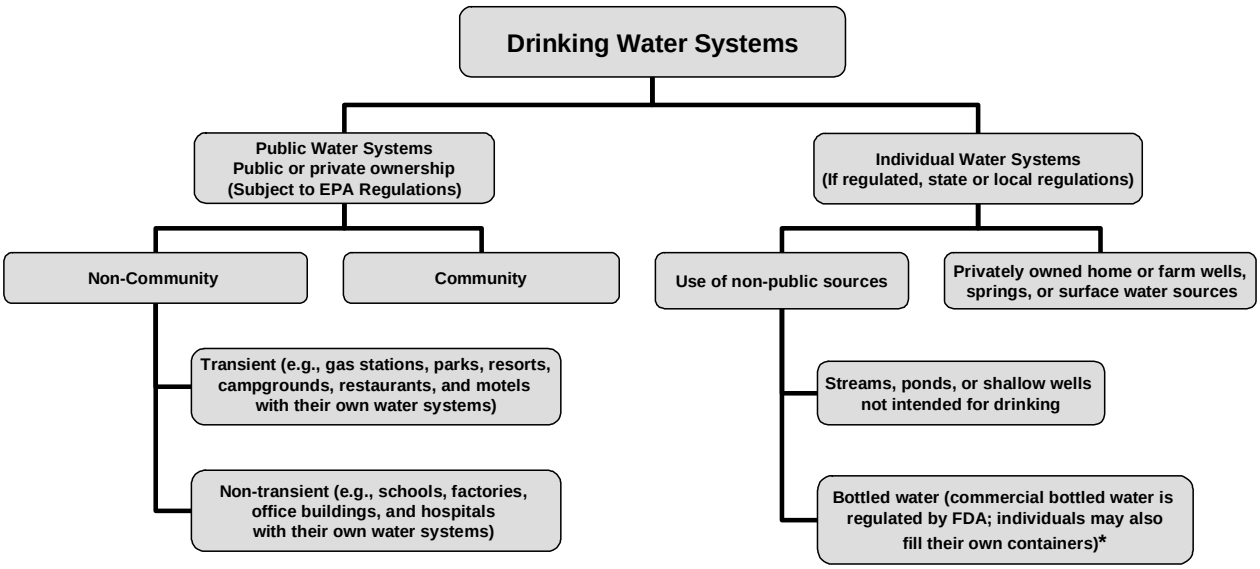
Classification of Investigations of Waterborne Disease Outbreaks in the United States

Class	Epidemiologic Data	Water-quality Data
I	Adequate Data were provided about exposed and unexposed persons, and the relative risk or odds ratio was $\geq$2, or the p-value was $\leq$0.05	Provided and adequate Historical information or laboratory data (e.g., the history that a chlorinator malfunctioned or a water main broke, no detectable free-chlorine residual, or the presence of coliforms in the water)
II	Adequate	Not provided or inadequate (e.g., laboratory testing of water not done)
III	Provided, but limited Epidemiologic data were provided that did not meet the criteria for Class I, or the claim was made that ill persons had no exposures in common besides water, but no data were provided.	Provided and adequate
IV	Provided, but limited	Not provided or inadequate

was optimally conducted" (Lee et al., 2002) or that all information requested on the report form was provided. Although anecdotal reports of possible waterborne illness are not included, outbreaks with limited epidemiologic evidence may be included (Craun et al., 2001). During 1992-1996, 29% of the reported WBDOs had limited epidemiologic evidence (classification III); in none of the WBDOs were both the epidemiologic and water quality evidence limited (classification IV) (Craun et al., 2001). A classification of II or III should not be interpreted to mean that investigations were inadequate or incomplete (Lee et al., 2002; Blackburn et al., 2004). Outbreaks and the resulting investigations occur under various circumstances, and not all outbreaks can or should be rigorously investigated (Lee et al., 2002; Blackburn et al., 2004). In addition, outbreaks that affect few persons are more likely to receive a classification of III, rather than I, on the basis of the relatively limited sample size available for analysis (Lee et al., 2002; Blackburn et al., 2004). By establishing guidelines to include WBDOs with limited evidence, investigators are encouraged to report outbreaks which may have been difficult to investigate or where some of the findings may not be conclusive (Craun et al., 2001).

The CDC and U.S. EPA also classify each water system associated with a waterborne outbreak as having one of the following deficiencies: untreated surface water; untreated groundwater; treatment deficiency (e.g., temporary interruption of disinfection, inadequate disinfection, and inadequate or no filtration); distribution system deficiency (e.g., cross-connection, contamination of water mains during construction or repair, and contamination of a storage facility); and unknown or miscellaneous deficiency (e.g., contaminated ice, faucets, containers, or bottled water).

Water sources are identified as either surface water, groundwater, or mixed (both surface water and groundwater sources). Public drinking water systems that may be associated with outbreaks are classified as either community or noncommunity based on definitions of the SDWA; drinking water-associated outbreaks involving private, individual water systems are also tabulated (Figure A-1). Individual water systems serve families that do not have access to a public system. Drinking water outbreaks are also associated with the ingestion of water not intended for consumption, contaminated bottled water, and contamination of water or ice contaminated at its point of use (e.g., a contaminated water faucet or serving container). Waterborne outbreaks associated with cruise ships are not included in the waterborne outbreak surveillance system.



*Footnote: In some instances, bottled water is used in lieu of a community supply or by non-community systems

FIGURE A-1

Types of Drinking Water Systems Used for Outbreak Classification

A.3. CASES OF ILLNESS AND SEVERITY OF ILLNESS

In the surveillance system, *the primary unit of analysis is an outbreak, not an individual case of a waterborne disease*. However, information is requested on the report form about the actual and estimated numbers of cases of illness, cases hospitalized and fatalities. The report form also requests information about the actual and estimated numbers of persons exposed (at risk), incubation period, duration of illness, the number of patient specimens (e.g., stool, vomitus, serum) examined and laboratory findings.

The case definition will vary among the outbreaks depending upon the suspected etiology and the signs and symptoms that are considered important by each investigator. The report form requests information about patient histories and the number of persons with various symptoms. The symptoms highlighted on the report form include diarrhea, vomiting, cramps, fever, nausea, rash, and conjunctivitis. Information about the number of stools per day may also be used to define a case, and stools may be further described as watery, loose or containing mucus or blood (CDC 52.12; Benenson, 1995). If a separate investigative report is enclosed, the specific case definition is usually provided. Otherwise, the case definition must be assumed from information provided on the report form. The report form specifically requests information about the number of persons with diarrhea at a frequency of three stools per day or diarrhea with an alternative definition to be provided by the investigator. The report form also requests information about a confirmed or suspected etiology.

The information requested on the standard report form can help describe the cases and impact associated with a specific outbreak, but investigators may not provide complete information about all of the measures that are considered important for estimating the outbreak's impact. The primary purpose of an investigation is to identify the cause of the outbreak so that steps can be taken to stop the outbreak, and this presumes that the recognition of a WBDO is timely. If water is implicated in an outbreak investigation where cases are continuing to occur, the focus will be on understanding the circumstances that led to the outbreak and developing corrective measures to ensure that the water is safe. In addition, WBDOs may be retrospectively investigated to identify the etiologic agent and water system deficiencies. In this case, limited information may be available to the investigator. Thus, identification of the full impact of the WBDO may be of secondary importance, depending on the suspected etiology, population at risk, and available resources. Illnesses among travelers and tourists may be geographically dispersed making it difficult to recognize all cases. Also, there has

been controversy surrounding reported WBDOs and the possible over estimation of cases (Craun et al., 2001).

As previously noted, the cases reported in the surveillance system may be based on limited information. In addition, cases may be reported in several ways. Reported cases may be either an actual or estimated number, and the reported cases may be based on signs and symptoms or may be confirmed by laboratory analysis of specimens. If both actual and estimated case counts are included on the outbreak report form, the CDC tabulates the estimated case count if the study population was sampled randomly or the estimated count was calculated by using the attack rate (Lee et al., 2002).

Recurring methodological problems may also limit the information about waterborne transmission. For example, an outbreak may impact relatively few persons making it difficult to identify a waterborne association, or there may be a large number of asymptomatic infections or mild illnesses that are not able to be identified because of the lack of resources. In addition, not all WBDO investigations identify both primary and secondary cases to assess the full impact of the outbreak. Primary cases are persons who are exposed to and infected by contaminated water; secondary cases are persons who are infected by and became ill after contact with primary case-patients. Primary cases can be a source of secondary infection, since some waterborne pathogens are easily spread by person-to-person transmission (Craun et al., 2001). The standard report form does not distinguish between primary and secondary cases; this information is available only from comments that may be noted on the remarks section of the report form or separate reports attached to the form. If primary cases and secondary cases are reported, only primary cases are included in the database.

A.4. LIMITATIONS OF THE SURVEILLANCE DATA

The key limitation of the data collected as part of the surveillance system is that the information pertains to *outbreaks* of waterborne disease. The reported statistics do not include *endemic or sporadic* cases of waterborne disease that are not recognized as an outbreak, and the epidemiologic trends and water-quality concerns observed in outbreaks might not necessarily reflect or correspond with trends associated with endemic waterborne illness. Endemic disease is the usual ongoing prevalence of a disease in a population or geographic area, and specifically-designed epidemiologic studies are needed to provide a quantitative estimate of the risk attributable to drinking water. The CDC and U.S. EPA are currently conducting epidemiologic studies of endemic waterborne disease risks, and these risks are not considered in our analyses.

Since the surveillance is passive and outbreak reporting is voluntary, the surveillance statistics represent only a portion of the waterborne outbreaks that occur in the United States. The thoroughness of reporting varies, and the epidemiologic information (e.g., population exposed, attack rates, cases and severity of illness) may be inconsistent or sparse. Thus, not all of the cases that occurred may be included in the outbreak reports. As previously noted, cases of Illness may also be overestimated due to recall or other epidemiologic biases or inadequate information about the size of the exposed population (Craun and Frost, 2002; Craun et al., 2001). For example, in the Milwaukee cryptosporidiosis outbreak, the largest waterborne outbreak reported in the U.S., an extensive investigation was conducted and considerable efforts went into estimating the cases of illness and their severity (Mac Kenzie et al., 1994; Hoxie et al., 1997; Naumova et al., 2003; Proctor et al., 1998; McDonald et al., 2001). There are few outbreaks where similar efforts were expended to estimate the number of cases and their severity. However, even with these efforts, there is still uncertainty about the outbreak's impact on Milwaukee residents. Hunter and Syed (2001) suggest that cases attributed to the waterborne outbreak were greatly overestimated, and a study of *Cryptosporidium*-specific antibody responses in children by McDonald et al. (2001) suggest that infection was much more widespread than previously appreciated. Unfortunately, McDonald et al. provided no information about symptoms or severity of cryptosporidiosis in the infected children.

In addition, not all waterborne outbreaks are recognized and investigated and not all investigated outbreaks are reported to CDC or U.S. EPA. For example, outbreaks occurring in national parks, tribal lands, or military bases may not be reported to state or local authorities (Blackburn et al., 2004). There are few estimates of the number of waterborne outbreaks that may go unrecognized and unreported (Craun, 1986; Hopkins et al., 1985), and studies have not been performed that assess the sensitivity of the surveillance system regarding unrecognized and unreported outbreaks (Blackburn et al., 2004). Thus, any estimates of underreporting of outbreaks should be viewed with caution.

Blackburn et al. (2004) suggest that data in the surveillance system markedly underestimate the true incidence of waterborne outbreaks. In part, this is because multiple factors influence whether waterborne outbreaks are recognized and investigated by local or state public health agencies. These include public awareness of the outbreak, availability of laboratory testing, requirements for reporting diseases, and resources available to the local health departments for surveillance and investigation of probable outbreaks. In addition, changes in the capacity of local and state public health

agencies and laboratories to detect an outbreak might influence the numbers of outbreaks reported in each state relative to others. Thus, the states with the majority of outbreaks reported during this period might not be the states where the majority of outbreaks actually occurred. An increase in the number of outbreaks reported could either reflect an actual increase in outbreaks or a change in sensitivity of surveillance practices. As with any passive surveillance system, accuracy of the data depends greatly on the reporting agencies (state, local and territorial health departments in this case). Thus, independent of the recognition or investigation of a given outbreak, reporting bias can influence the final data.

Most likely to be recognized and investigated are outbreaks of acute illness characterized by a short incubation period, outbreaks that result in serious illness or symptoms requiring medical treatment, and outbreaks of recently recognized etiologies for which laboratory methods have become more sensitive or widely available (Blackburn et al., 2004). Increased reporting often occurs as etiologies become better recognized, water system deficiencies identified, and state surveillance activities and laboratory capabilities increase (Frost et al., 1995, 1996; Hopkins et al., 1985). Recommendations for improving waterborne disease outbreak investigations include increased laboratory support for clinical and water analyses, enhanced surveillance activities, and assessment of sources of potential bias (Craun et al., 2001; Frost et al., 2003; Hunter et al., 2003).

During the 30-year surveillance period (1971-2000) included in our analysis, an etiologic agent was not identified in 55% of the reported waterborne outbreaks of infectious disease. The identification of the etiologic agent of a waterborne outbreak depends on the timely recognition of the outbreak so that appropriate clinical and environmental samples can be collected. Additionally, the laboratory involved must have the capability to test for a particular organism in order to detect it. For example, routine testing of stool specimens at laboratories will include tests for the presence of enteric bacterial pathogens and might also include an ova and parasite examination. However, *Cryptosporidium spp.*, among the most commonly reported waterborne pathogens, is often not included in standard ova and parasite examinations, and thus must be specifically requested (Jones et al., 2004). Additionally, though norovirus testing is being performed more commonly, testing for other viral agents is rarely done (Blackburn et al., 2004).

Outbreaks classified as AGI are likely caused by a variety of etiologic agents. The symptoms and severity of illness associated with these outbreaks can vary based on the etiologic agent. Testing, when conducted, may not identify an agent. For

example during 1999-2000, laboratory testing for enteric pathogens was conducted in five of the 17 AGI outbreaks; stool specimens were negative for parasitic and bacterial pathogens in four outbreaks. In the fifth AGI outbreak affecting only two persons, stool specimens tested negative for *Giardia intestinalis* but positive for *Blastocystis hominis*. Whether *B*. *hominis* was the cause of the reported illness was unclear because its pathogenicity has been debated in the scientific community (Lee et al., 2002). Suspected pathogens were noted by investigators of the following four additional AGI outbreaks on the basis of symptoms of illness: norovirius was suspected in one outbreak and *G*. *intestinalis* in one outbreak; a bacterial pathogen and an unknown chemical were each suspected in the two remaining outbreaks.

Finally, collection of water-quality data which can help determine contamination sources or identify the waterborne pathogen depends primarily on local and state statutory requirements, the availability of investigative personnel, and the technical capacity of the laboratories that test the water. Not all reported waterborne outbreaks have adequate information about waterborne pathogens, indicators of fecal contamination, or likely sources of the contamination.

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DEPARTMENT OF HEALTH & HUMAN SERVICES
Centers for Disease Control and Prevention
National Center for Infectious Diseases
Atlanta, GA 30333

WATERBORNE DISEASES OUTBREAK REPORT

This form should be used to report outbreaks of illness after consumption or use of water intended for drinking, as well as outbreaks associated with exposure (ingestion, contact or inhalation) to recreational water.

CDC USE ONLY
–
___ ___ ___ ___ ___ ___

Form Approved
OMB No. 0920-0004

SUBMITTED COPIES OF THIS FORM SHOULD INCLUDE AS MUCH INFORMATION AS POSSIBLE; BUT THE COMPLETION OF EVERY ITEM IS NOT REQUIRED.

1. TYPE of EXPOSURE:
- ☐ Drinking water
- ☐ Recreational water
- ☐ Other: _____

2. LOCATION of OUTBREAK:
State: _____
City or Town: _____
County: _____

3. DATE of OUTBREAK:
(Date first case became ill):
☐☐ Mo. ☐☐ Day ☐☐ Yr.

4. NUMBERS OF:

	Actual	Estimated
Persons exposed:		
Persons ill:		
Hospitalized:		
Fatalities:		

5. HISTORY of EXPOSED PERSONS:
Enter the no. of persons with the following symptoms:

NO. OF PERSONS INTERVIEWED: ☐
NO. OF INTERVIEWED PERSONS WHO WERE ILL: ☐

Diarrhea (≥3 stools/day): ____ Diarrhea (other): ____/(Specify definition): _____
Visible blood in stools: ____ Nausea: ____ Fever: ____ Vomiting: ____ Cramps: ____
Eye infections: ____ Ear infections: ____ Skin infections: ____ Rash: ____ Dermatitis: ____
Respiratory symptoms: ____ Other, specify: _____

6. INCUBATION PERIOD:

	Hrs.	Days
Shortest:	☐	☐
Longest:	☐	☐
Median:	☐	☐
Mean:	☐	☐

7. DURATION of ILLNESS:

	Hrs.	Days
Shortest:	☐	☐
Longest:	☐	☐
Median:	☐	☐
Mean:	☐	☐

8. SPECIMENS EXAMINED from PATIENTS: (stool, vomitus, serum, etc.)

SPECIMEN	No. PERSONS	FINDINGS
EXAMPLE *Stool*	*11*	*8 Giardia intestinalis 3 negative*

9. ETIOLOGY of OUTBREAK:

Agent (If not known enter "Unk.")	Diagnostic Certainty: Confirmed	Suspected
Pathogen:	☐	☐
Chemical:	☐	☐
Other:	☐	☐

Comments: _____

10a. EPIDEMIOLOGIC DATA: (e.g., vehicle/source - specific attack rates; dose-response curve, **attach local and/or state report if available**)

EXPOSURE (vehicle/source)	Number of Persons EXPOSED: ILL	NOT ILL	TOTAL	% ILL	Number of Persons NOT EXPOSED: ILL	NOT ILL	TOTAL	% ILL	ODDS/RISK RATIO (If available)	p VALUE or CONFIDENCE INTERVAL (If available)

☐ **No data were collected from comparison groups to estimate risk but water was the only common source shared by persons who were ill.**

10b. Comments: _____

11. WATER SUPPLY CHARACTERISTICS: *(check all that apply for drinking water or recreational water)*

*If recreational water outbreak, this refers to recreational water treatment

a) TYPE OF DRINKING WATER SUPPLY:
- ☐ Community or Municipal
  - ☐ City or County (Name: _____)
  - ☐ Subdivision
  - ☐ Trailer Park
- ☐ Noncommunity (does not obtain water from a community water system, but has developed/maintained its own water supply)
  - ☐ Camp, Cabin, Recreational area
  - ☐ School
  - ☐ Restaurant
  - ☐ Hotel, Motel
  - ☐ Church
  - ☐ Other: _____
- ☐ Individual household supply
- ☐ Bottled water
- ☐ Other: _____
- ☐ Unknown

b) WATER SOURCE OR SETTING:
- ☐ Well
- ☐ Spring/Hot spring
- ☐ River, Stream
- ☐ Lake, Pond, Reservoir
- ☐ Ocean
- ☐ Pool
  - ☐ Waterpark
  - ☐ Community/municipal
  - ☐ Subdivision/neighborhood apartment
  - ☐ Hotel/motel
  - ☐ Membership club
  - ☐ Private home
  - ☐ Kiddie/wading
- ☐ Fountain
  - ☐ Interactive
  - ☐ Ornamental
  - ☐ Waterpark
- ☐ Hot tub
- ☐ Whirlpool/spa pool
- ☐ Other: _____
- ☐ Unknown

c) WATER TREATMENT PROVIDED:*
- ☐ No treatment
- ☐ Disinfection
  - ☐ Chlorine
  - ☐ Chlorine and Ammonia (chloramine)
  - ☐ Bromine
  - ☐ Ozone
  - ☐ U.V.
  - ☐ Other: _____
  - ☐ Unknown
- ☐ Coagulation and/or Flocculation
- ☐ Settling (sedimentation)
- ☐ Filtration at purification plant (**don't** include home filters) or pool
  - ☐ Rapid sand
  - ☐ Slow sand
  - ☐ Diatomaceous earth
  - ☐ Other: _____
  - ☐ Unknown
- ☐ Other: _____
- ☐ Unknown

IF RECREATIONAL EXPOSURE, PROCEED TO QUESTION (13), OTHERWISE PROCEED TO (12a).

12. FACTORS CONTRIBUTING TO DRINKING WATER CONTAMINATION: (check **all** that apply) *See 16

a) Contamination at the water source:

- ☐ Overflow of sewage
- ☐ Underground seepage of sewage
- ☐ Septic system drainage
- ☐ Flooding, heavy rains
- ☐ Use of a back-up source of water by a water utility
- ☐ Improper construction or location of well or spring
- ☐ Contamination of wells through limestone or fissured rock
- ☐ Contamination from wild/domestic animals
- ☐ Chemical pollution
- ☐ Algal bloom
- ☐ Other: _____
- ☐ Unknown

b) Water treatment deficiencies:

- ☐ No disinfection
- ☐ Temporary interruption of disinfection
- ☐ Chronically inadequate disinfection
- ☐ No filtration
- ☐ Inadequate filtration
- ☐ Deficiencies in other treatment processes
- ☐ Other: _____
- ☐ Unknown

c) Contamination in the water distribution system or home plumbing:

- ☐ Cross connection of potable and non-potable water pipes resulting in back siphonage (negative pressure or backflow)
- ☐ Contamination of mains during construction or repair
- ☐ Contamination of storage facility
- ☐ Contamination in building/home
- ☐ Other: _____
- ☐ Unknown

d) OTHER REASONS/CONTRIBUTING FACTORS FOR CONTAMINATION OF WATER (eg. corrosive water):

.....

13. ROUTE OF ENTRY FOR RECREATIONAL EXPOSURE:

☐ Accidental ingestion ☐ Intentional ingestion ☐ Contact ☐ Inhalation ☐ Other: _____ ☐ Unknown

14. FACTORS CONTRIBUTING TO RECREATIONAL WATER CONTAMINATION: (check **all** that apply) *See 16

a) FRESH OR MARINE WATER (e.g. lakes, rivers, oceans):

- ☐ High bather density/load
- ☐ Fecal accident by bather(s)
- ☐ Use by diaper/toddler aged children
- ☐ Overflow or release of sewage
- ☐ Flooding, heavy rains
- ☐ Stagnant water
- ☐ Water Temperature ≥ 30°C
- ☐ Chemical pollution
- ☐ Algal bloom
- ☐ Animal feces observed near site
- ☐ Agricultural/animal production in watershed
- ☐ Unprotected watershed
- ☐ Other: _____
- ☐ Unknown

b) FILTERED AND/OR DISINFECTED SWIMMING VENUES (e.g. swimming pools, water parks, hot tubs, whirlpools/spa pools):

- ☐ High bather density/load
- ☐ Fecal accident by bather(s)
- ☐ Use by diaper/toddler aged children
- ☐ No disinfection
- ☐ Inadequate disinfection
- ☐ Poor monitoring of disinfection levels
- ☐ Cross contamination (specify _____)
- ☐ Combined adult/child pool filtration systems
- ☐ No filtration
- ☐ Inadequate filtration
- ☐ Other: _____
- ☐ Unknown

15. WATER SPECIMENS EXAMINED: (provide information for routine samples collected **before** and **during** the outbreak investigation as well as for any special lab studies)

☐ NONE TESTED

		LABORATORY RESULTS		
ITEM	DATE	MICROBIOLOGY	DISINFECTANT RESIDUAL	TURBIDITY
EXAMPLES *Tap Water*	*10/11/01*	*Total coliforms - none found in two 100ml samples; Giardia - 10 cysts/100L*	*0.5 mg/L*	*0.1 NTU*
Untreated Raw Water	*11/02/01*	*23 fecal coliforms per 100 ml*	*Not Done*	*10.0 NTU*
System History	*Prev. 3 mos*	*MCL for total coliforms exceeded month before outbreak*	*NA*	*>MCL*
Source Water	*Prev. 2 wks*	*Heavy runoff, high turbidity*	*NA*	*5.0 NTU*

16. REMARKS: Clarify for sections 12 and 14 which checked items are confirmed or are suspected factors

Briefly describe the unusual aspects of the outbreak and/or the outbreak investigation not covered above. Attach epidemic curve and summary report, if available.

.....

.....

.....

Person to contact for information about water quality or water system:

_____

_____

Person completing form: (please print)

NAME: _____

AGENCY: _____

E-MAIL: _____

TEL. NO: (___ ___ ___) ___ ___ ___ - ___ ___ ___ ___ (area code)

DATE OF REPORT: ___ ___ / ___ ___ / ___ ___ (MO. / DAY / YR.)

Date investigation initiated:

___ ___ / ___ ___ / ___ ___ (MO. / DAY / YR.)

Note: Epidemic and laboratory assistance for the investigation of a waterborne outbreak is available upon request by the State Health Department to the Centers for Disease Control and Prevention. To improve national surveillance of outbreaks of waterborne diseases, please send a copy of this report, your internal report, and the questionnaire used in the epidemiologic investigation (if available) to:

Centers for Disease Control and Prevention
Division of Parasitic Diseases
Attention: Waterborne Disease Coordinator
4770 Buford Highway, NE, Mailstop F22
Atlanta, GA 30341-3724

U.S. DEPARTMENT OF HEALTH & HUMAN SERVICES
Centers for Disease Control and Prevention
National Center for Infectious Diseases
Atlanta, GA 30333

WATERBORNE DISEASES OUTBREAK REPORT

This form should be used to report outbreaks of illness after consumption or use of water intended for drinking, as well as outbreaks associated with exposure (ingestion, contact or inhalation) to recreational water, **excluding** wound infections caused by water-related organisms.

CDC USE ONLY
– __ __ __ __ __ __

Form Approved
OMB No. 0920-0004

SUBMITTED COPIES OF THIS FORM SHOULD INCLUDE AS MUCH INFORMATION AS POSSIBLE; BUT THE COMPLETION OF EVERY ITEM IS NOT REQUIRED.

1. TYPE of EXPOSURE:
- ☐ Water intended for drinking
- ☐ Recreational

2. LOCATION of OUTBREAK:
State: _____
City or Town: _____
County: _____

3. DATE of OUTBREAK:
(Date first case became ill):
☐☐ Mo. ☐☐ Day ☐☐ Yr.

4. NUMBERS OF:

	Actual	Estimated
Persons exposed:		
Persons ill:		
Hospitalized:		
Fatalities:		

5. HISTORY of EXPOSED PERSONS:
Enter the no. of persons with the following symptoms:

NO. OF HISTORIES OBTAINED: ☐
NO. OF INTERVIEWED PERSONS WHO WERE ILL: ☐

Diarrhea (3 stools/day): _____ Diarrhea (other): No. _____ / definition: _____
Visible blood in stools: _____ Nausea: _____ Fever: _____ Conjunctivitis: _____ Cough: _____
Vomiting: _____ Cramps: _____ Rash: _____ Otitis externa: _____
Other, specify: _____

6. INCUBATION PERIOD: (HOURS)
Shortest: _____
Longest: _____
Median: _____

7. DURATION of ILLNESS: (DAYS)
Shortest: _____
Longest: _____
Median: _____

8. SPECIMENS EXAMINED from PATIENTS: (stool, vomitus, serum, etc.)

SPECIMEN	No. PERSONS	FINDINGS
EXAMPLE Stool	11	8 *Giardia lamblia* 3 negative

9. ETIOLOGY of OUTBREAK:

Agent (If not known enter "Unk.")	Diagnostic Certainty: Confirmed	Suspected
Pathogen:	☐	☐
Chemical:	☐	☐
Other:	☐	☐

Comments:

10a. EPIDEMIOLOGIC DATA: (e.g., vehicle/source - specific attack rates; attack rate by quantity of vehicle consumed, **attach report if available**)

EXPOSURE (vehicle/source)	Number of Persons EXPOSED: ILL	**NOT** ILL	TOTAL	% ILL	Number of Persons **NOT** EXPOSED: ILL	**NOT** ILL	TOTAL	% ILL	ODDS RATIO (If available)	p VALUE or CONFIDENCE INTERVAL (If available)

Comments:

11. WATER SUPPLY CHARACTERISTICS: *(check all that apply for both drinking water and recreational water)*

a) TYPE OF DRINKING WATER SUPPLY:
- ☐ Community or Municipal
  - ☐ City or County (Name: _____)
  - ☐ Subdivision
  - ☐ Trailer Park
- ☐ Noncommunity (does not obtain water from a community water system, but has developed/maintained its own water supply)
  - ☐ Camp, Cabin, Recreational area
  - ☐ School
  - ☐ Restaurant
  - ☐ Hotel, Motel
  - ☐ Church
  - ☐ Other: _____
- ☐ Individual household supply
- ☐ Bottled water
- ☐ Other: _____

b) WATER SOURCE OR SETTING: (check source that was cause of outbreak)
- ☐ Well
- ☐ River, Stream
- ☐ Lake, Pond, Reservoir
- ☐ Spring
- ☐ Ocean
- ☐ Community/municipal pool
- ☐ Waterpark
- ☐ Subdivision/neighborhood apartment pool
- ☐ Hotel/motel/club pool
- ☐ Private home pool
- ☐ Kiddie/wading (e.g., backyard splash pool)
- ☐ Hot tub
- ☐ Whirlpool
- ☐ Other: _____
- ☐ Unknown

c) WATER TREATMENT PROVIDED:
- ☐ No treatment
- ☐ Disinfection
  - ☐ Chlorine
  - ☐ Chlorine and Ammonia (chloramine)
  - ☐ Ozone
  - ☐ U.V.
  - ☐ Other: _____
  - ☐ Unknown
- ☐ Coagulation and/or Flocculation
- ☐ Settling (sedimentation)
- ☐ Filtration at purification plant (**don't** include home filters) or pool
  - ☐ Rapid sand
  - ☐ Slow sand
  - ☐ Diatomaceous earth
  - ☐ Other: _____
  - ☐ Unknown
- ☐ Other: _____
- ☐ Unknown

IF RECREATIONAL EXPOSURE, PROCEED TO QUESTION (13), OTHERWISE PROCEED TO (12a).

12. FACTORS CONTRIBUTING TO DRINKING WATER CONTAMINATION: (check **all** that apply)

a) AT SOURCE:

- ☐ Overflow of sewage
- ☐ Flooding, heavy rains
- ☐ Underground seepage of sewage
- ☐ Use of a back-up source of water by a water utility
- ☐ Improper construction or location of well or spring
- ☐ Contamination through creviced limestone or fissured rock
- ☐ Unknown
- ☐ Other: _____

b) AT TREATMENT PLANT:

- ☐ No disinfection
- ☐ Temporary interruption of disinfection
- ☐ Chronically inadequate disinfection
- ☐ No filtration
- ☐ Inadequate filtration
- ☐ Deficiencies in other treatment processes
- ☐ Unknown
- ☐ Other: _____

c) IN DISTRIBUTION SYSTEM:

- ☐ Cross connection
- ☐ Back siphonage
- ☐ Contamination of mains during construction or repair
- ☐ Contamination of storage facility
- ☐ Unknown
- ☐ Other: _____

d) OTHER REASONS FOR CONTAMINATION OF WATER:

13. FACTORS CONTRIBUTING TO RECREATION WATER CONTAMINATION: (check **all** that apply)

a) FRESH OR MARINE WATER (e.g. lakes, rivers, oceans):

- ☐ Excessive bather density/load
- ☐ Fecal accident by bather(s)
- ☐ Overflow or release of sewage
- ☐ Flooding, heavy rains
- ☐ Unprotected watershed
- ☐ Agricultural/animal production in watershed
- ☐ Increased water temperature
- ☐ Stagnant water
- ☐ Open access to wild animal population
- ☐ Unknown
- ☐ Other: _____

b) FILTERED AND/OR DISINFECTED SWIMMING VENUES (e.g. swimming pools, water parks, hot tubs, whirlpools):

- ☐ Excessive bather density/load
- ☐ Fecal accident by bather(s)
- ☐ No disinfection
- ☐ Inadequate disinfection
- ☐ Poor monitoring of disinfection levels
- ☐ Cross contamination (specify _____)
- ☐ Combined adult/child pool filteration systems
- ☐ No filtration
- ☐ Inadequate filtration
- ☐ Unknown
- ☐ Other: _____

14. WATER SPECIMENS EXAMINED: (provide information for routine samples collected **before** and **during** the outbreak investigation as well as for any special lab studies)

☐ NONE TESTED

ITEM	DATE	LABORATORY RESULTS: MICROBIOLOGY	LABORATORY RESULTS: DISINFECTANT RESIDUAL	LABORATORY RESULTS: TURBIDITY
EXAMPLES Tap Water	10/11/99	No coliforms	0.5 mg/L	0.1 NTU
Untreated Raw Water	11/02/99	23 fecal coliforms	Not Done	10.0 NTU
Tap Water	11/12/99	*Giardia*; 10 total coliforms per 100 ml	0	2.0 NTU

15. REMARKS: Briefly describe the unusual aspects of the outbreak and/or the outbreak investigation not covered above. Attach epidemic curve and summary report, if available.

Name of reporting agency:	Person completing form: (please print)	Date investigation initiated:
_____	NAME: _____ TEL. NO: (_____) ___-____ (area code)	__ __ / __ __ / __ __ (MO. DAY YR.)
_____	TITLE: _____ DATE OF REPORT: __ __ / __ __ / __ __ (MO. DAY YR.)	

Note: Epidemic and laboratory assistance for the investigation of a waterborne outbreak is available upon request by the State Health Department to the Centers for Disease Control and Prevention. To improve national surveillance of outbreaks of waterborne diseases, please send a copy of this report, your internal report, and the questionnaire used in the epidemiologic investigation (if available) to:

Centers for Disease Control and Prevention
Division of Parasitic Diseases
Attention: Waterborne Disease Coordinator
4770 Buford Highway, NE, Mailstop F22
Atlanta, GA 30341-3724

U.S. DEPARTMENT OF HEALTH & HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Center for Infectious Diseases
Atlanta, GA 30333

WATERBORNE DISEASES OUTBREAK REPORT

This form should be used to report outbreaks of illness after consumption or use of water intended for drinking, as well as outbreaks associated with exposure (ingestion, contact or inhalation) to recreational water, **excluding** wound infections caused by water-related organisms.

CDC USE ONLY
–
__ __ __ __ __ __

Form Approved
OMB No. 0920-0004

SUBMITTED COPIES OF THIS FORM SHOULD INCLUDE AS MUCH INFORMATION AS POSSIBLE; BUT THE COMPLETION OF EVERY ITEM IS NOT REQUIRED.

1. TYPE of EXPOSURE:
- ☐ Water intended for drinking
- ☐ Recreational

2. LOCATION of OUTBREAK:
State: _____
City or Town: _____
County: _____

3. DATE of OUTBREAK:
(Date first case became ill):
Mo. Day Yr.

4. NUMBERS OF:

	Actual	Estimated
Persons exposed:		
Persons ill:		
Hospitalized:		
Fatalities:		

5. HISTORY of EXPOSED PERSONS:
Enter the no. of persons with the following symptoms:

NO. OF HISTORIES OBTAINED: ____ NO. OF INTERVIEWED PERSONS WHO WERE ILL: ____

Diarrhea (3 stools/day): _____ Diarrhea (other): No. _____ / definition Ð _____
Visible blood in stools: _____ Cramps: _____ Conjunctivitis: _____ Other, specify: _____
Vomiting: _____ Fever: _____ Otitis externa: _____ _____
Nausea: _____ Rash: _____ Cough: _____ _____

6. INCUBATION PERIOD: (HOURS)
Shortest: _____
Longest: _____
Median: _____

7. DURATION of ILLNESS: (DAYS)
Shortest: _____
Longest: _____
Median: _____

8. SPECIMENS EXAMINED from PATIENTS: (stool, vomitus, serum, etc.)

	SPECIMEN	No. PERSONS	FINDINGS
EXAMPLE	Stool	11	8 *Giardia lamblia* 3 negative

9. ETIOLOGY of OUTBREAK:

Agent (If not known enter "Unk.")	Diagnostic Certainty: Confirmed	Suspected
Pathogen:	☐	☐
Chemical:	☐	☐
Other:	☐	☐

Comments:

10a. EPIDEMIOLOGIC DATA: (e.g., vehicle/source - specific attack rates; attack rate by quantity of vehicle consumed)

EXPOSURE (vehicle/source)	Number of Persons EXPOSED: ILL	NOT ILL	TOTAL	% ILL	Number of Persons NOT EXPOSED: ILL	NOT ILL	TOTAL	% ILL	ODDS RATIO (If available)	p VALUE or CONFIDENCE INTERVAL (If available)

Comments:

10b. VEHICLE/SOURCE RESPONSIBLE: *(implicated by epidemiologic evidence in [10a])* _____

11. WATER SUPPLY CHARACTERISTICS: *(skip to question 12, if recreational exposure)*

a) TYPE OF WATER SUPPLY:
- ☐ Community or Municipal
  - ☐ City or County (Name: _____)
  - ☐ Subdivision
  - ☐ Trailer Park
- ☐ Noncommunity (does not obtain water from a community water system, but has developed/maintained its own water supply)
  - ☐ Camp, Cabin, Recreational area
  - ☐ School
  - ☐ Restaurant
  - ☐ Hotel, Motel
  - ☐ Church
  - ☐ Other: _____
- ☐ Individual household supply
- ☐ Bottled water
- ☐ Other: _____

b) WATER SOURCE: (check source that was cause of outbreak)
- ☐ Well
- ☐ River, Stream
- ☐ Lake, Pond, Reservoir
- ☐ Spring
- ☐ Other: _____
- ☐ Unknown

c) WATER TREATMENT PROVIDED: (check **all** that apply)
- ☐ No treatment
- ☐ Disinfection
  - ☐ Chlorine
  - ☐ Chlorine and Ammonia (chloramine)
  - ☐ Ozone
  - ☐ Other: _____
  - ☐ Unknown
- ☐ Coagulation and/or Flocculation
- ☐ Settling (sedimentation)
- ☐ Filtration at purification plant (**don't** include home filters)
  - ☐ Rapid sand
  - ☐ Slow sand
  - ☐ Diatomaceous earth
  - ☐ Other: _____
  - ☐ Unknown
- ☐ Other: _____
- ☐ Unknown

IF RECREATIONAL EXPOSURE, PROCEED TO QUESTION (12) AND THEN (13d), OTHERWISE PROCEED TO (13a).

12. RECREATIONAL EXPOSURE:

a) Route of Entry:

☐ Intentional ingestion ☐ Contact
☐ Accidental ingestion ☐ Inhalation

b) Type of Exposure:

☐ Swimming pool ☐ Hot Tub
☐ Lake, Pond ☐ Whirlpool
☐ River, Stream ☐ Other:_____

Describe the setting: (e.g., health spa, rafting trip, etc.)

13. FACTORS CONTRIBUTING TO WATER CONTAMINATION: (check **all** that apply)

a) AT SOURCE:

☐ Overflow of sewage ☐ Use of a back-up source of water by a water utility ☐ Other: _____
☐ Flooding, heavy rains ☐ Improper construction or location of well or spring ☐ Unknown
☐ Underground seepage of sewage ☐ Contamination through creviced limestone or fissured rock

b) AT TREATMENT PLANT:

☐ No disinfection ☐ No filtration ☐ Other: _____
☐ Temporary interruption of disinfection ☐ Inadequate filtration ☐ Unknown
☐ Chronically inadequate disinfection ☐ Deficiencies in other treatment processes

c) IN DISTRIBUTION SYSTEM:

☐ Cross connection ☐ Contamination of mains during construction or repair ☐ Other: _____
☐ Back siphonage ☐ Contamination of storage facility ☐ Unknown

d) OTHER REASONS FOR CONTAMINATION OF WATER: (include recreational exposures here)

14. WATER SPECIMENS EXAMINED: (provide information for routine samples collected **before** and **during** the outbreak investigation as well as for any special lab studies)

☐ NONE TESTED

		LABORATORY RESULTS		
ITEM	DATE	MICROBIOLOGY	DISINFECTANT RESIDUAL	TURBIDITY
EXAMPLES Tap Water	10/11/91	No coliforms	0.5 mg/L	0.1 NTU
Untreated Raw Water	11/02/91	23 fecal coliforms	Not Done	10.0 NTU
Tap Water	11/12/91	*Giardia*; 10 total coliforms per 100 ml	0	2.0 NTU

15. REMARKS: Briefly describe the unusual aspects of the outbreak and/or the outbreak investigation not covered above. Attach epidemic curve and summary report, if available.

Name of reporting agency:

_____

_____

Person completing form: (please print)

NAME: _____ TEL. NO: (_____) ___-____
area code

TITLE: _____ DATE OF REPORT: __/__/__
MO. DAY YR.

Date investigation initiated:

__/__/__
MO. DAY YR.

Note: Epidemic and laboratory assistance for the investigation of a waterborne outbreak is available upon request by the State Health Department to the Centers for Disease Control and Prevention. To improve national surveillance of outbreaks of waterborne diseases, please send a copy of this report, your internal report, and the questionnaire used in the epidemiologic investigation (if available) to:

Centers for Disease Control and Prevention
Division of Parasitic Diseases
Attention: Waterborne Disease Coordinator
4770 Buford Highway, NE, Mailstop F22
Atlanta, GA 30341-3724

DEPARTMENT OF
HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL
CENTER FOR INFECTIOUS DISEASES
ATLANTA, GEORGIA 30333

INVESTIGATION OF A WATERBORNE OUTBREAK

Form Approved
OMB No. 0920-0004

1. Where did the outbreak occur?

_____ (1-2) City or Town _____ County _____

2. Date of outbreak: (Date of onset of 1st case)

_____ (3-8)

3. Indicate actual (a) or estimated (e) numbers:

Persons exposed _____ (9-11)
Persons ill _____ (12-14)
Hospitalized _____ (15-16)
Fatal cases _____ (17)

4. History of exposed persons:

No. histories obtained _____ (18-20)
No. persons with symptoms _____ (21-23)
Nausea _____ (24-26) Diarrhea _____ (33-35)
Vomiting _____ (27-29) Fever _____ (36-38)
Cramps _____ (30-32)
Other, specify (39) _____

5. Incubation period (hours):

Shortest _____ (40-42) Longest _____ (43-45)
Median _____ (46-48)

Shortest _____ (49-51) Longest _____ (52-54)
Median _____ (55-57)

7. Epidemiologic data (e.g., attack rates [number ill/number exposed] for persons who did or did not eat or drink specific food items or water, attack rate by quantity of water consumed, anecdotal information) * (58)

ITEMS SERVED	NUMBER OF PERSONS WHO **ATE** OR **DRANK** SPECIFIED FOOD OR WATER				NUMBER WHO **DID NOT EAT OR DRINK** SPECIFIED FOOD OR WATER			
	ILL	NOT ILL	TOTAL	PERCENT ILL	ILL	NOT ILL	TOTAL	PERCENT ILL

8. Vehicle responsible (item incriminated by epidemiologic evidence): (59-60)

9. Water supply characteristics

(A) Type of water supply** (61)

- ☐ Municipal or community supply (Name _____)
- ☐ Individual household supply
- ☐ Semi-public water supply
  - ☐ Institution, school, church
  - ☐ Camp, recreational area
  - ☐ Other, _____
- ☐ Bottled water

(B) Water source *(check all applicable):*

- ☐ Well
- ☐ Spring
- ☐ Lake, pond
- ☐ River, stream

(C) Treatment provided *(circle treatment of each source checked in B):*

a	b	c	d	a. no treatment
a	b	c	d	b. disinfection only
a	b	c	d	c. purification plant – coagulation, settling, filtration, disinfection *(circle those applicable)*
a	b	c	d	d. other _____

10. Point where contamination occurred: (66)

☐ Raw water source ☐ Treatment plant ☐ Distribution system

*See CDC 52.13 (Formerly 4.245) Investigation of a Foodborne Outbreak, Item 7.

Municipal or community water supplies are public or investor owned utilities. **Individual water supplies are wells or springs used by single residences. **Semipublic** water systems are individual-type water supplies serving a group of residences or locations where the general public is likely to have access to drinking water. These locations include schools, camps, parks, resorts, hotels, industries, institutions, subdivisions, trailer parks, etc., that do not obtain water from a municipal water system but have developed and maintain their own water supply.

CDC 52.12 (Formerly 4.461)
REV. 7-81

This report is authorized by law (Public Health Service Act, 42 USC 241).
While your response is voluntary, your cooperation is necessary for the understanding and control of the disease.

11. Water specimens examined: (67)
(Specify by "X" whether water examined was original (drunk at time of outbreak) or check-up (collected before or after outbreak occurred)

ITEM	ORIGINAL	CHECK UP	DATE	FINDINGS		BACTERIOLOGIC TECHNIQUE (e.g., fermentation tube, membrane filter)
				Quantitative	Qualitative	
Examples: Tap water	X		6/12/74	10 fecal coliforms per 100 ml.		
Raw water		X	6/2/74	23 total coliforms per 100 ml.		

12. Treatment records: *(Indicate method used to determine chlorine residual):*
Example: Chlorine residual — One sample from treatment plant effluent on 6/11/74 — trace of free chlorine
Three samples from distribution system on 6/12/74 — no residual found

13. Specimens from patients examined (stool, vomitus, etc.) (68)

SPECIMEN	NO. PERSONS	FINDINGS
Example: Stool	11	8 *Salmonella typhi*
		3 negative

14. Unusual occurrence of events:
Example: Repair of water main 6/11/74; pit contaminated with sewage, no main disinfection. Turbid water reported by consumers 6/12/74.

15. Factors contributing to outbreak *(check all applicable):*

- ☐ Overflow of sewage
- ☐ Seepage of sewage
- ☐ Flooding, heavy rains
- ☐ Use of untreated water
- ☐ Use of supplementary source
- ☐ Water inadequately treated
- ☐ Interruption of disinfection
- ☐ Inadequate disinfection
- ☐ Deficiencies in other treatment processes
- ☐ Cross-connection
- ☐ Back-siphonage
- ☐ Contamination of mains during construction or repair
- ☐ Improper construction, location of well/spring
- ☐ Use of water not intended for drinking
- ☐ Contamination of storage facility
- ☐ Contamination through creviced limestone or fissured rock
- ☐ Other (specify) _____

16. Etiology: (69-70)
Pathogen _____
Chemical _____
Other _____

(71)
Suspected 1
Confirmed . . . . . 2 *(Circle one)*
Unknown 3

17. Remarks: *Briefly describe aspects of the investigation not covered above, such as unusual age or sex distribution; unusual circumstances leading to contamination of water; epidemic curve; control measures implemented; etc. (Attack additional page if necessary)*

Name of reporting agency: (72)

Investigating Official:	**Date of investigation:**

Note: Epidemic and Laboratory assistance for the investigation of a waterborne outbreak is available upon request by the State Health Department to the Centers for Disease Control, Atlanta, Georgia 30333.

To improve national surveillance, please send a copy of this report to:
Centers for Disease Control
Attn: Enteric Diseases Branch, Bacterial Diseases Division
Center for Infectious Diseases
Atlanta, Georgia 30333

Submitted copies should include as much information as possible, but the completion of every item is not required.

CDC 52.12 (Formerly 4.461) (BACK)
REV. 7-81

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL
BUREAU OF EPIDEMIOLOGY
ATLANTA, GEORGIA 30333

E. INVESTIGATION OF A WATERBORNE OUTBREAK

FORM APPROVED
OMB NO. 68-R557

1. Where did the outbreak occur?

State _____ (1-2) City or Town _____ County _____

2. Date of outbreak: (Date of onset of 1st case)

_____ (3-8)

3. Indicate actual (a) or estimated (e) numbers:

Persons exposed _____ (9-11)
Persons ill _____ (12-14)
Hospitalized _____ (15-16)
Fatal cases _____ (17)

4. History of exposed persons:

No. histories obtained _____ (18-20)
No. persons with symptoms _____ (21-23)
Nausea _____ (24-26) Diarrhea _____ (33-35)
Vomiting _____ (27-29) Fever _____ (36-38)
Cramps _____ (30-32)
Other, specify (39) _____

5. Incubation period (hours):

Shortest _____ (40-42) Longest _____ (43-45)
Median _____ (46-48)

6. Duration of illness (hours):

Shortest _____ (49-51) Longest _____ (52-54)
Median _____ (55-57)

7. Epidemiologic data (e.g., attack rates [number ill/number exposed] for persons who did or did not eat or drink specific food items or water, attack rate by quantity of water consumed, anecdotal information) * (58)

ITEMS SERVED	NUMBER OF PERSONS WHO ATE OR DRANK SPECIFIED FOOD OR WATER				NUMBER WHO DID NOT EAT OR DRINK SPECIFIED FOOD OR WATER			
	ILL	NOT ILL	TOTAL	PERCENT ILL	ILL	NOT ILL	TOTAL	PERCENT ILL

8. Vehicle responsible (item incriminated by epidemiologic evidence): (59-60) _____

9. Water supply characteristics

(A) Type of water supply** (61)

- ☐ Municipal or community supply (Name _____)
- ☐ Individual household supply
- ☐ Semi-public water supply
  - ☐ Institution, school, church
  - ☐ Camp, recreational area
  - ☐ Other, _____
- ☐ Bottled water

(B) Water source *(check all applicable):* (62-65)

- ☐ Well
- ☐ Spring
- ☐ Lake, pond
- ☐ River, stream

(C) Treatment provided *(circle treatment of each source checked in B):*

a b c d a. no treatment
a b c d b. disinfection only
a b c d c. purification plant — coagulation, settling, filtration, disinfection *(circle those applicable)*
a b c d d. other _____

10. Point where contamination occurred: (66)

☐ Raw water source ☐ Treatment plant ☐ Distribution system

*See HSM 4.245 (NCDC) Investigation of a Foodborne Outbreak, Item 7.

Municipal or community water supplies are public or investor owned utilities. **Individual water supplies are wells or springs used by single residences. **Semipublic** water systems are individual-type water supplies serving a group of residences or locations where the general public is likely to have access to drinking water. These locations include schools, camps, parks, resorts, hotels, industries, institutions, subdivisions, trailer parks, etc., that do not obtain water from a municipal water system but have developed and maintain their own water supply.

CDC 4.461
2-75

This report is authorized by law (Public Health Service Act, 42 USC 241) and is also recommended by the Conference of State and Territorial Epidemiologists. While your response is voluntary, your cooperation is necessary for the understanding and control of the diseases.

11. Water specimens examined: (67)
(Specify by "X" whether water examined was original (drunk at time of outbreak) or check-up (collected before or after outbreak occurred)

ITEM	ORIGINAL	CHECK UP	DATE	FINDINGS		BACTERIOLOGIC TECHNIQUE (e.g., fermentation tube, membrane filter)
				Quantitative	Qualitative	
Examples: Tap water	X		6/12/74	10 fecal coliforms per 100 ml.		
Raw water		X	6/2/74	23 total coliforms per 100 ml.		

12. Treatment records: *(Indicate method used to determine chlorine residual):*
Example: **Chlorine residual — One sample from treatment plant effluent on 6/11/74 — trace of free chlorine**
Three samples from distribution system on 6/12/74 — no residual found

13. Specimens from patients examined (stool, vomitus, etc.) (68)

SPECIMEN	NO. PERSONS	FINDINGS
Example: Stool	**11**	**8 *Salmonella typhi***
		3 negative

14. Unusual occurrence of events:
Example: Repair of water main 6/11/74; pit contaminated with sewage, no main disinfection. Turbid water reported by consumers 6/12/74.

15. Factors contributing to outbreak *(check all applicable):*

- ☐ Overflow of sewage
- ☐ Seepage of sewage
- ☐ Flooding, heavy rains
- ☐ Use of untreated water
- ☐ Use of supplementary source
- ☐ Water inadequately treated
- ☐ Interruption of disinfection
- ☐ Inadequate disinfection
- ☐ Deficiencies in other treatment processes
- ☐ Cross-connection
- ☐ Back-siphonage
- ☐ Contamination of mains during construction or repair
- ☐ Improper construction, location of well/spring
- ☐ Use of water not intended for drinking
- ☐ Contamination of storage facility
- ☐ Contamination through creviced limestone or fissured rock
- ☐ Other (specify) _____

16. Etiology: (69-70)
Pathogen _____
Chemical _____
Other _____

(71)
Suspected 1
Confirmed . . . . . 2 *(Circle one)*
Unknown 3

17. Remarks: *Briefly describe aspects of the investigation not covered above, such as unusual age or sex distribution; unusual circumstances leading to contamination of water; epidemic curve; control measures implemented; etc. (Attack additional page if necessary)*

Name of reporting agency: (72)

Investigating Official:

Date of investigation:

Note: Epidemic and Laboratory assistance for the investigation of a waterborne outbreak is available upon request by the State Health Department to the Center for Disease Control, Atlanta, Georgia 30333.

To improve national surveillance, please send a copy of this report to: Center for Disease Control
Attn: Enteric Diseases Branch, Bacterial Diseases Division
Bureau of Epidemiology
Atlanta, Georgia 30333

Submitted copies should include as much information as possible, but the completion of every item is not required.

CDC 4.461 (Back)
2-75

APPENDIX B

OUTBREAK INVESTIGATION METHODS
ENTERIC WATERBORNE DISEASE OUTBREAKS IN DRINKING WATER 1971-2000

TABLE B-1

Case Counts Reported in Enteric Waterborne Disease Outbreaks in Drinking Water by Time Period, 1971-2000

How Cases Were Reported	1971 to 1980		1981 to 1990		1991 to 2000	
	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases
Cases, Actual	192	16,817	171	13,467	100	5,959
Cases, Estimated	49	52,162	56	49,587	43	426,181
Unknown	44	5,552	8	182	2	55
Total	285	74,531	235	63,236	145	432,195

TABLE B-2

Case Counts Reported in Enteric Waterborne Disease Outbreaks in Drinking Water by Type of System, 1971-2000

How Cases Were Reported	Community		Individual		Non-community	
	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases
Cases, Actual	170	18,421	64	944	229	16,878
Cases, Estimated	72	491,786	6	409	70	35,735
Unknown	12	4,063	12	155	30	1,571
Total	254	514,270	82	1,508	329	54,184

TABLE B-3

How Reported Cases Were Estimated in Enteric Waterborne Disease Outbreaks in Drinking Water by Time Period, 1971-2000

How Cases Were Estimated	1971 to 1980		1981 to 1990		1991 to 2000	
	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases
Cohort survey	26	21,419	23	20,661	15	2,191
Unknown	8	14,797	15	7,445	6	1,885
Guess	9	2,051	11	4,053	13	1,847
Random survey	5	12,695	6	17,343	8	420,188
Cohort and physician survey	1	1,200	1	85	0	0
Physician Survey	0	0	0	0	1	70
Total	49	52,162	56	49,587	43	426,181

TABLE B-4

How Reported Cases Were Estimated in Enteric Waterborne Disease Outbreaks in Drinking Water by Type of System, 1971-2000

How Cases Were Estimated	Community		Individual		Non-community	
	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases
Cohort survey	33	24,800	0	0	31	19,471
Unknown	15	17,038	1	150	13	6,939
Guess	6	457	4	174	23	7,320
Random survey	17	448,291	0	0	2	1,935
Cohort and physician survey	1	1,200	1	85	0	0
Physician Survey	0	0	0	0	1	70
Total	72	491,786	6	409	70	35,735

TABLE B-5

How Case Counts Were Obtained in Enteric Waterborne Disease Outbreaks in Drinking Water by Time Period, 1971-2000

How Actual Cases Were Obtained	1971 to 1980		1981 to 1990		1991 to 2000	
	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases
Cohort survey	96	7,310	88	4,062	59	4,328
Unknown	41	5,867	41	5,046	6	338
All population at risk surveyed	38	2,008	22	617	30	814
Cohort and physician survey	12	1,457	8	1,912	2	203
Laboratory positive cases	3	39	6	759	2	153
Physician, hospital survey	2	136	2	15	1	123
Random survey	0	0	4	1,056	0	0
Total	192	16,817	171	13,467	100	5,959

TABLE B-6

How Case Counts Were Obtained in Enteric Waterborne Disease Outbreaks in Drinking Water by Type of System, 1971-2000

How Actual Cases Were Obtained	Community		Individual		Non-community	
	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases	Number of Reported Outbreaks	Number of Reported Cases
Cohort survey	95	6,196	23	541	125	8,963
Unknown	36	7,148	6	35	46	4,068
All population at risk surveyed	13	770	33	364	44	2,305
Cohort and physician survey	13	2,324	1	2	8	1,246
Laboratory positive cases	7	912	1	2	3	37
Physician, hospital survey	2	15	0	0	3	259
Random survey	4	1,056	0	0	0	0
Total	170	18,421	64	944	229	16,878

APPENDIX C

MONETARY DISEASE BURDEN BY AGENT FOR WATERBORNE OUTBREAKS THAT OCCURRED BETWEEN 1971-2000

TABLE C-1

Reported and Projected Economic Burden by Agent

Etiological Agent (General)	Sum of Physician Visit Cost Reported[a]	Sum of Physician Visit Cost Projected[b]	Sum of ER Visit Costs Reported	Sum of ER Visit Costs Projected	Sum of Hospital Costs Reported[c]	Sum of Self-Medication Costs Reported	Sum of Self-Medication Costs Projected	Sum of Ill Prod Losses by Severity Distribution Reported	Sum of Ill Prod Losses by Severity Distribution Projected	Sum of Caregiver Prod Losses by Severity Distribution Reported	Sum of Caregiver Prod Losses by Severity Distribution Projected	Sum of Cost-of-Illness Reported	Sum of Cost-of-Illness Projected
AGI	$52,245	$569,043	$338,088	$3,601,049	$1,753,300	$185,593	$186,834	$3,461,602	$8,010,151	$374,037	$1,590,689	$6,164,865	$15,711,067
C. jejuni	$3,290	$20,962	$4,202	$6,056	$426,041	$12,474	$12,495	$456,138	$682,838	$45,079	$96,115	$947,224	$1,244,508
Cyclospora	$0	$69	$0	$233	$0	$47	$47	$0	$5,036	$0	$657	$47	$6,042
Crypto-sporidium	$1,308,060	$1,367,993	$0	$4,685,423	$37,676,877	$938,671	$939,661	$91,916,470	$99,091,214	$11,897,897	$14,368,841	$143,737,976	$158,130,010
E. coli O157:H7 & other	$0	$5,720	$0	$2,804	$640,412	$3,436	$3,443	$247,688	$370,715	$31,408	$68,521	$922,944	$1,091,615
E. coli O157:H7 & *Campylobacter*	$0	$2,922	$0	$1,432	$372,699	$1,758	$1,762	$0	$155,769	$0	$31,814	$374,457	$566,398
En. histolytica	$0	$13	$0	$44	$5,547	$9	$9	$0	$4,367	$0	$1,100	$5,556	$11,081
Giardia	$9,159	$563,629	$38,966	$316,074	$301,022	$63,149	$63,848	$2,095,553	$10,152,171	$170,632	$2,398,476	$2,678,481	$13,795,219
Hepatitis A	$6,450	$50,286	$764	$28,718	$217,647	$1,868	$1,919	$127,936	$1,442,056	$28,334	$470,908	$383,000	$2,211,534
Norovirus	$0	$70,046	$1,910	$16,534	$27,560	$29,086	$29,170	$226,076	$613,410	$18,395	$83,025	$303,027	$839,745
P. shigelloides	$0	$224	$0	$110	$14,341	$134	$134	$0	$7,539	$0	$1,332	$14,475	$23,681
Rotavirus	$9,417	$9,417	$0	$2,220	$0	$3,920	$3,921	$0	$234,798	$0	$31,509	$13,337	$281,864

TABLE C-1 cont.

Etiological Agent (General)	Sum of Physician Visit Cost Reported[a]	Sum of Physician Visit Cost Projected[b]	Sum of ER Visit Costs Reported	Sum of ER Visit Costs Projected	Sum of Hospital Costs Reported[c]	Sum of Self-Medication Costs Reported	Sum of Self-Medication Costs Projected	Sum of Ill Prod Losses by Severity Distribution Reported	Sum of Ill Prod Losses by Severity Distribution Projected	Sum of Caregiver Prod Losses by Severity Distribution Reported	Sum of Caregiver Prod Losses by Severity Distribution Projected	Sum of Cost-of-Illness Reported	Sum of Cost-of-Illness Projected
Salmonella, non-typhoid spp.	$0	$11,982	$0	$5,873	$491,487	$7,140	$7,155	$111,960	$496,439	$16,313	$77,422	$626,900	$1,090,358
S. enterica serovar Typhi	$129	$452	$0	$517	$2,347,990	$704	$705	$148,645	$1,029,667	$42,198	$294,728	$2,539,667	$3,674,059
Shigella	$0	$34,402	$3,056	$338,658	$1,245,232	$20,515	$20,621	$347,149	$993,442	$48,152	$190,040	$1,664,105	$2,822,395
SRSV	$0	$374	$0	$88	$0	$155	$156	$1,892	$2,206	$145	$296	$2,193	$3,120
V. cholerae	$0	$105	$0	$51	$14,036	$63	$64	$0	$6,880	$0	$1,544	$14,099	$22,680
Yersinia	$0	$385	$0	$189	$118,071	$235	$236	$55,867	$58,254	$12,766	$13,911	$186,939	$191,046
Grand Total	$1,388,750	$2,708,025	$386,986	$9,006,075	$45,652,263	$1,268,959	$1,272,179	$99,196,978	$123,356,953	$12,685,357	$19,720,927	$160,579,292	$201,716,422

[a] Reported refers to measure as reported in the WBDOSS (see Chapter 1).
[b] Projected includes estimated measures (see Chapter 2).
[c] Hospital cases and costs not projected. See Section 2.1 for explanation.